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Via email to rob.decandia@dec.ny.gov

August 10, 2018

Mr. Robert D. DeCandia Jr. P.E.
NYSDEC, Remedial Bureau A
Division of Environmental Remediation
625 Broadway
Albany, New York 12233-7015

Re: Groundwater Extraction/Hydraulic Containment
Expanded Pumping Test Summary, Findings, and Recommendations
Frost Street Sites: Site ID #s 1-30043 I, L, M
New Cassel Industrial Area, Westbury, New York

Dear Mr. DeCandia:

On behalf of the Frost Street Parties, EnSafe Inc. presents the results of the Expanded Pumping Test performed at the Frost Street Sites in support of the Groundwater Extraction/Hydraulic Containment System (groundwater remedy for Operable Unit [OU] 2) in the attached *Expanded Pumping Test Report*.

The pumping test was performed in accordance with the *Expanded Pumping Test Supplemental Work Plan* (EnSafe, March 7, 2018) that was approved by New York State Department of Environmental Conservation (NYSDEC) on March 8, 2018. The pumping test details, deviations from the work plan due to site conditions, groundwater model results, and recommended pumping rates are summarized below; additional details can be found in the attached report.

<u>Pumping Test Summary</u>

Survey

In order to facilitate the pumping test along with the as-built drawings and environmental easement/deed restriction, a site survey was performed in March and April 2018. The site was surveyed to horizontally and vertically locate property features, metes and bounds, and the OU1 and OU2 remediation systems' components (air sparge, soil vapor extraction, groundwater extraction, and monitoring wells; trenching; and above ground controls and structures). The survey information collected will be incorporated into the Final Engineering Report and Site Management Plan; and well elevations were utilized for the pumping test and the subsequent groundwater model.

Site Preparation

Prior to performance of the expanded pumping test, the pumps were hung in the two deep extraction wells pumps had already been installed in the two shallow wells). Carbon pretreatment was also procured as it was expected to be required when EX-1A and/or EX-1B are pumping alone. Following the installation of the pumps and carbon pretreatment, a brief operational test was performed on March 19 and 20, 2018.

Prior to pressure transducer installation, the targeted wells were inspected and gauged for condition and suitability for inclusion in the pumping test. Pressure transducers were then installed in the following wells; this list includes the original 16 wells proposed in the RAWP, plus 13 more:

- EX-1A, B, C, D
- FSMW-5A, B
- FSMW-6A, B
- FSMW-8A, B, C, D
- FSMW-12
- FSMW-13A, B, C
- FSMW-14A, B, C
- FSMW-16A, B
- FSMW-17A,B
- FSMW-18A, B
- FSMW-19A, B, C, D

Pressure transducers were programmed to collect data once every minute throughout the duration of the test (Phase I and II, described below).

Baseline Data Collection

Following the system test on March 19 and 20, 2018, the system was shut off from Thursday, March 22 through Wednesday, March 28, 2018 to collect baseline data.

Phase I

The Phase I pumping test was performed over the course of two weeks in accordance with the original scope presented in Section 2.12 of the RAWP. Following the initial shutdown period, each of the four extraction wells were made operational, individually (one per day), at design pumping rates for 8 hours, and then shut down for 16 hours. Following this one week period of individual well testing, all four extraction wells were put in service at design pumping rates for one week. Additional details are provided below:

- Thursday, March 29, 2018: EX-1A at 30 gallons per minute (gpm) for 8 hours
- Friday, March 30, 2018: EX-1B at 30 gpm for 8 hours
- Monday, April 2, 2018: EX-1C at 48 gpm for 8 hours

- Tuesday, April 3, 2018 EX-1D at 48 gpm for 8 hours
- Wednesday, April 4, 2018: EX-1A, B, C, D at rates listed above through Wednesday, April 11, 2018
  (The pumps were shut off temporarily on April 6, 2018 for a half hour to plumb EX-1C and EX-1D in an attempt to achieve a higher pH.)

Details and results from this phase of the testing are provided in the attached report. Overall, the aquifer responded rapidly to pumping when initiated and sustained the design pumping rates with stable drawdown.

Phase II

The system remained off for one week to allow the aquifer to stabilize prior to initiating Phase II. After this stabilization period, EX-1A was made operational at the design flow rate for one week, then shut down for one week. EX-1B was then made operational at the design flow rate for one week, then shut down for one week. EX-1A and EX-1B were then made operational together, at design pumping rates, for one week, then shut down. Details of Phase II of the test are provided below:

- Wednesday, April 11, 2018: System off for 1 week for stabilization, through Wednesday, April 18, 2018
- Wednesday, April 18, 2018: EX-1A at 30 gpm for 1 week through Tuesday, April 24, 2018
  (Due to an alarm, the test was stopped and the pump in EX-1A shut off on Tuesday, April 24 at 5:39 PM. This is approximately 16 hours earlier than the intended stop, trigged by an "Emergency Stop" alarm at the panel of unknown origin. Troubleshooting the following day noted no issues with the pump or system.)
- Tuesday, April 24, 2018: System off for 1 week for stabilization, through Wednesday, May 2, 2018
- Wednesday, May 2, 2018: EX-1B at 30 gpm for 1 week through Wednesday, May 9, 2018
- Wednesday, May 9, 2018: System off for 1 week for stabilization, through Wednesday, May 16, 2018
- Wednesday, May 16, 2018: EX-1A and 1B at 30 gpm each for 1 week through Wednesday, May 23, 2018
- Wednesday, May 23, 2018: System off for 1 week for stabilization, through Wednesday, May 30, 2018

Details and results from this phase of the testing is provided in the attached report. Consistent with Phase II, the aquifer responded rapidly to pumping when initiated and sustained the design pumping rates with stable drawdown.

After this shutdown period, the four extraction wells were made operational at design pumping rates until approval is received for revised rates as described below. Due to low pH issues and pretreatment requirements, this was delayed until June 15, 2018.

Analytical Data

During the course of the pumping test, extracted water samples were collected for laboratory analysis for volatile organic compounds (VOCs) to evaluate the need for carbon pretreatment. These samples were collected from each extraction well four times: immediately after initial startup (all four wells), at the end of each individual well test in Phase I (all four wells), at the end of the combined well tests in Phase I (all four wells), and at the end of the combined pumping test in Phase II (EX-1A and EX-1B). The unvalidated analytical data is provided in the attached **Table 1**.

Rainfall

Historical precipitation data from a nearby weather station at Republic Airport in East Farmingdale, New York (approximately 8.5 miles southeast of the Frost Street Sites) was obtained from Weather Underground. Notable precipitation that occurred during the pumping test (greater than 0.1") is listed below.

- April 2, 2018 0.26"
- April 4, 2018 0.12"
- April 15, 2018 0.28"
- April 16 2018 1.57"
- April 19, 2018 0.12"
- April 25, 2018 0.23"
- April 27, 2018 0.21"
- May 10, 2018 0.11"
- May 12, 2018 0.15"
- May 15, 2018 0.28"
- May 16, 2018 0.36"
- May 17, 2018 0.55"
- May 19, 2018 0.84"
- May 22, 2018 0.11"

Downloads

In general, the pressure transducers were downloaded once per week, as listed below.

- March 27, 2018
- April 9, 2018
- April 16, 2018
- April 24, 2018
- April 30, 2018
- May 7, 2018
- May 14, 2018
- May 21, 2018
- May 29, 2018

<u>Groundwater Modeling</u>

The data collected during this pumping test was incorporated into a three-dimensional analytical model, to assess the pumping tests and to determine site-specific parameters for the layered and stratified aquifer. The site aquifer parameters were then in turn used as the initial inputs for a numerical flow model constructed using the modular three-dimensional finite-difference groundwater flow model (MODFLOW). The MODFLOW model was constructed using site-specific hydrogeology details and aquifer parameters to evaluate of the source of groundwater and hydraulic capture for the extraction wells operating individually and in concert (versus the analytical model previously used for design which utilized broad assumptions an aquifer characteristics). The report detailing the modeling efforts and subsequent results is attached to this letter.

Findings and Recommendations

The pumping test was performed, as approved, in a controlled setting in order to gather data regarding the capture zones of the extraction wells such that an effective and efficient remedial program may be established. The pumping test was successful at providing the data necessary to inform a comprehensive groundwater extraction program that meets the goals of the Record of Decision, Explanation of Significant Differences, and RAWP. The data gathered during the test reveal significant vertical influence and extraction well capture zones that were not anticipated during the design phase, leading to the conclusions and recommendations set forth below.

Pumping Rates

After analysis of the pump test data and subsequent groundwater model, it was determined that the design pumping rates yield a much larger capture zone than required to achieve contaminant capture at the site, shown on Figures 1 and 2. The groundwater model and subsequent outputs indicate the required capture zone, from the top of groundwater to 250 feet bgs, will be obtained by substantially reduced pumping rates as shown below and on Figures 3 and 4.

	Reduced Rates (gpm)
EX-1A	15
EX-1B	0
EX-1C	8
EX-1D	0

This pumping configuration is ideal because it yields the required capture zone presented in the RAWP that will effectively remove the groundwater contamination, while minimizing the volume of uncontaminated groundwater that is extracted. Operating the system in this way provides the following additional benefits:

- Consistency with NYSDEC DER-31 – Green Remediation: Operating the wells at reduced rates will “minimize the environmental footprint of cleanup actions” at the Frost Street Sites. This pumping configuration is much more sustainable than design rates because it is less disruptive to the environment and minimizes energy use, but is equally protective as the design pumping configuration.

- Minimizes Use of the Treatment Facility: Conveying uncontaminated groundwater to the treatment system under design pumping rates monopolizes system capacity that could otherwise be granted to other industrial users.
- Minimizes Operating Costs: Operating the wells at reduced rates will reduce operation and maintenance costs and extend the operational lifetime of the system components.

As such, we recommend running the system at the reduced pumping rates above, with the exception of EX-1C which will be operated at 13 gpm. (The current pumps cannot operate any lower than 13 gpm; in order to minimize system downtime, the existing equipment will be utilized).

The reduced pumping rates shown above are a substantial reduction from those presented in the RAWP, on which the system was designed, and can be attributed to the following:

- The pumping rates to achieve the design capture zone were analytically calculated using aquifer parameters from literature and nearby sites in the absence of site-specific data, and included a 1.5 design factor to account for uncertainties. The reduced pumping rates were calculated using a numerical model based on empirical, site-specific data, collected while the system operated at design rates in various configurations over a period of 2.5 months.
- The analytical calculation of the design pumping rates assumed the aquifer was homogeneous, which field efforts to date have shown is not the case. The numerical model allows discretization of the effects of pumping each vertical aquifer zone by assigning unique hydraulic properties to each of those zones, yielding a more accurate evaluation of pumping at the site.
- The analytical calculation of the design pumping rates assumed minimal vertical effects from pumping; the pumping test and subsequent groundwater model have shown a large vertical influence of pumping.

Carbon Pretreatment

Based on analytical data collected during this pumping test, carbon pretreatment is likely not required when pumping in this configuration (average total VOC concentration of the initial samples, shown in Table 1, is 0.58 ppm, less than the permit allowed 1 ppm). However, because the proposed pumping configuration is more “focused” on the groundwater contamination and it has not been tested in-situ, there is a possibility that carbon will be required. As such, one week after system startup at these revised rates, samples will be collected and analyzed for VOCs. If the combined effluent concentration exceed the permit limit of 1 part per million total VOCs, the pumping rates will be increased slightly and a sample recollected one week later until compliance with the discharge permit is achieved. Following this approach will minimize system downtime related to the installation of a carbon pretreatment system. The final pumping configuration that eliminates the need for carbon pretreatment will be documented in the Final Engineering Report and Site Management Plan.

The system will be made operational at the revised pumping rates above once NYSDEC's approval is obtained. If you have any questions or require additional information, please do not hesitate to contact me at 860-665-1140 or astark@ensafe.com.

Sincerely,

EnSafe, Inc., by

Alexandra M. J. Stark

Alexandra Stark, P.E.
Project Manager

I, Robert McCarthy, certify that I am currently a New York State registered professional engineer as defined in 6 NYCRR Part 375 and that this pumping test was performed in accordance with the Supplemental Work Plan and in accordance with all applicable statues and regulations and in substantial conformance with the DER Technical Guidance for Site Investigation and Remediation (DER-10).

Robert McCarthy, P.E.
Design Engineer, P.E. #082259

Attachments: Table 1
Figures 1 to 4
Groundwater Model Report

Copies:	T. Pupilla, Sanders Equities	*Via email to tpupilla@sandersequities.com*
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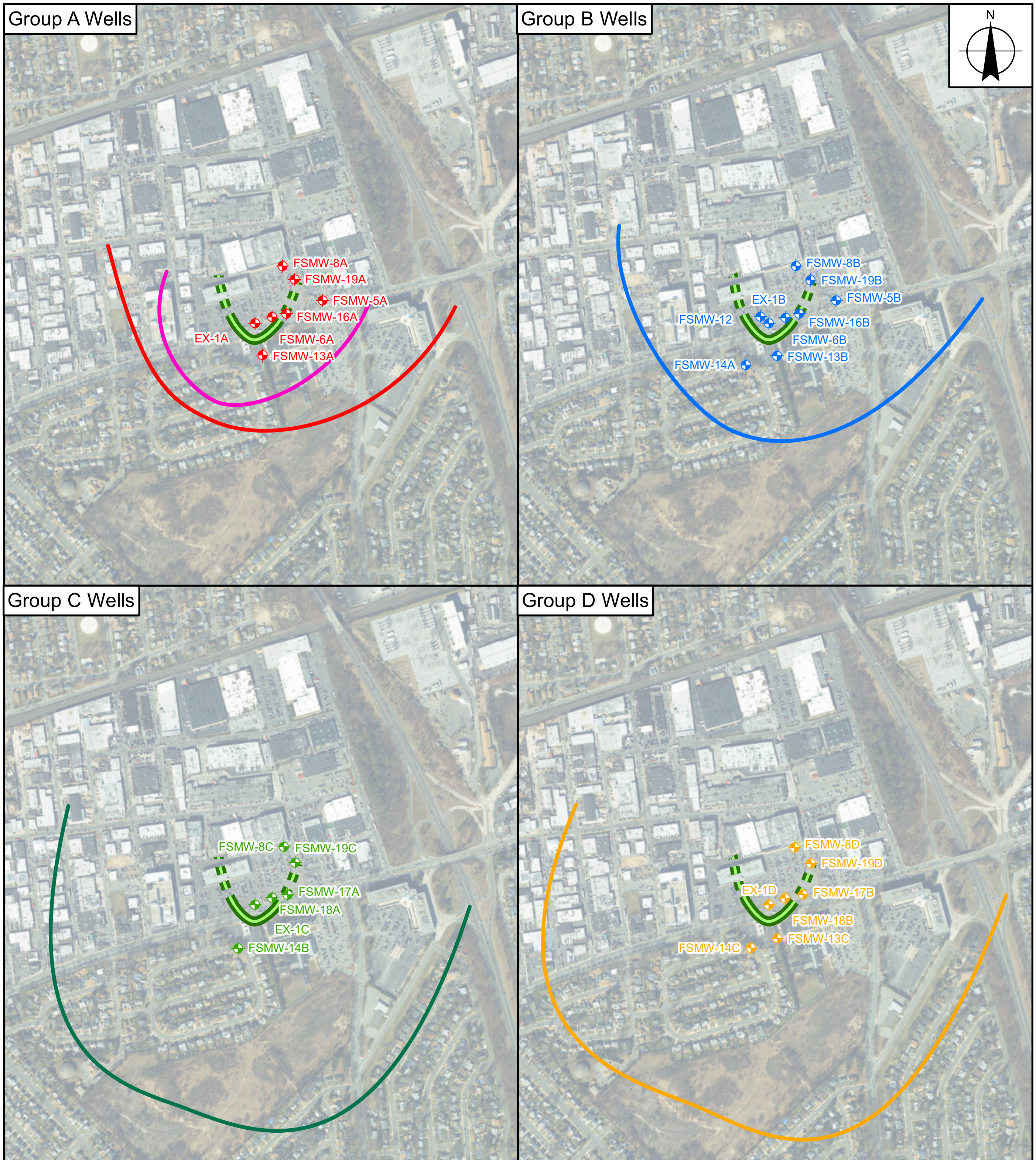
Attachments

Table 1 - Summary of Pump Test Analytical Data

	INITIAL BEFORE STARTUP				PHASE 1 PART 1 END EACH WELL AFTER 8 HOURS OF PUMPING ALONE				PHASE 1 PART 1 END EACH WELL AFTER 1 WEEK OF PUMPING ALL				PHASE 2 PART 1 END SHALLOW WELLS AFTER 1 WEEK PUMPING EACH ALONE		PHASE 2 PART 2 END SHALLOW WELLS AFTER 1 WEEK PUMPING EACH TOGETHER	
Well ID	**EX-1A**	**EX-1B**	**EX-1C**	**EX-1D**	**EX-1A**	**EX-1B**	**EX-1C**	**EX-1D**	**EX-1A**	**EX-1B**	**EX-1C**	**EX-1D**	**EX-1A**	**EX-1B**	**EX-1A**	**EX-1B**
Sample Date	**03/19/2018**	**03/19/2018**	**03/19/2018**	**03/19/2018**	**03/29/2018**	**03/30/2018**	**04/02/2018**	**04/03/2018**	**4/11/2018**	**4/11/2018**	**4/11/2018**	**4/11/2018**	**04/25/2018**	**05/09/2018**	**5/23/2018**	**5/23/2018**
Analyte (ppb):																
1,1,1-Trichloroethane	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	**0.34**	0.2 U	0.2 U	0.2 U	0.2 U
1,1,2,2-Tetrachloroethane	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.2 U	0.2 U	0.2 U	0.2 U
1,1,2-Trichloroethane	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.2 U	0.2 U	0.2 U	0.2 U
1,1-Dichloroethane	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	**0.26**	**0.62**	0.2 U	0.2 U	0.2 U	0.2 U
1,1-Dichloroethene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	**0.61 J**	**0.58**	0.5 U	0.5 U	**1.5**	0.2 U	0.2 U	0.2 U	0.2 U
1,2-Dichlorobenzene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.2 U	0.2 U	0.2 U	0.2 U
1,2-Dichloroethane	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.2 U	0.2 U	0.2 U	0.2 U
1,2-Dichloropropane	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.2 U	0.2 U	0.2 U	0.2 U
1,3-Dichlorobenzene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.2 U	0.2 U	0.2 U	0.2 U
1,4-Dichlorobenzene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.2 U	0.2 U	0.2 U	0.2 U
2-Chloroethyl vinyl ether	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	NA	NA	NA	NA	0.2 U	0.2 U	0.2 U	0.2 U
Benzene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.2 U	0.2 U	0.2 U	0.2 U
Bromodichloromethane	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.2 U	0.2 U	0.2 U	0.2 U
Bromoform	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.2 U	0.2 U	0.2 U	0.2 U
Bromomethane	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.2 U	0.2 U	0.2 U	0.2 U
Carbon tetrachloride	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.2 U	0.2 U	0.2 U	0.2 U
Chlorobenzene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.2 U	0.2 U	0.2 U	0.2 U
Chloroethane	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.2 U	0.2 U	0.2 U	0.2 U
Chloroform	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	**0.45 J**	0.5 U	0.5 U	0.5 U	**1.2**	0.2 U	0.2 U	0.2 U	0.2 U
Chloromethane	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.2 U	0.2 U	0.2 U	0.2 U
cis-1,2-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	**17**	**16**	0.5 U	**2.3**	NA	NA	NA	NA
cis-1,3-Dichloropropene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.4 U	0.4 U	0.4 U	0.4 U	0.2 U	0.2 U	0.2 U	0.2 U
Dibromochloromethane	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.2 U	0.2 U	0.2 U	0.2 U
Ethylbenzene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.2 U	0.2 U	0.2 U	0.2 U
Methyl tert-butyl ether	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	1 U	1 U	1 U	1 U	0.2 U	0.2 U	0.2 U	0.2 U
Methylene chloride	**6.2 B**	**5.1 B**	**5.4 B**	**6 B**	5 U	5 U	5 U	5 U	0.5 U	0.5 U	0.5 U	0.5 U	5 U	**6 B**	5 U	5 U
Tetrachloroethene	**300 D**	**1,500 D**	**340 D**	**110**	**480 D**	**560 D**	**78**	**14**	**820**	**1,000**	**3.2**	**3.9**	**250 D**	**380 D**	**160 D**	**340 D**
Toluene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.2 U	0.2 U	0.2 U	0.2 U
trans-1,2-Dichloroethene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.2 U	0.2 U	0.2 U	0.2 U
trans-1,3-Dichloropropene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.4 U	0.4 U	0.4 U	0.4 U	0.2 U	0.2 U	0.2 U	0.2 U
Trichloroethene	**8.4**	**28**	**12**	**4.7**	**16**	**13**	**3.2**	**4.5**	**41**	**40**	**4.6**	**13**	**12**	**13**	**6.3**	**12**
Trichlorofluoromethane	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.2 U	0.2 U	0.2 U	0.2 U
Vinyl chloride	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.2 U	0.2 U	0.2 U	0.2 U
m,p-Xylene	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.5 U	0.5 U	0.5 U	0.5 U	0.4 U	0.4 U	0.4 U	0.4 U
o-Xylene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.2 U	0.2 U	0.2 U	0.2 U
Xylenes, Total	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	1 U	1 U	1 U	1 U	0.6 U	0.6 U	0.6 U	0.6 U
Acetone	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	NA	NA	NA	NA	5 U	5 U	5 U	5 U
Total VOCs (ppb)	**314.6**	**1533.1**	**357.4**	**120.7**	**496**	**573**	**81.2**	**19.56**	**878.58**	**1,056**	**8.06**	**22.86**	**262**	**399**	**166.3**	**352**



LEGEND

- GROUP A WELLS - SCREENS 50-80 FAMSL
- GROUP B WELLS - SCREENS 119-149 FAMSL
- GROUP C WELLS - SCREENS 159-184 FAMSL
- GROUP D WELLS - SCREENS 221-249 FAMSL
- DESIGN SHALLOW CAPTURE ZONE (50 TO 150 FEET BGS) (30 GPM) (DASHED WHERE INFERRED)
- DESIGN DEEP CAPTURE ZONE (150 TO 250 FEET BGS) (48 GPM) (DASHED WHERE INFERRED)
- MODEL SIMULATED DESIGN CAPTURE ZONE EX-1A1
- MODEL SIMULATED DESIGN CAPTURE ZONE EX-1A2
- MODEL SIMULATED DESIGN CAPTURE ZONE EX-1B
- MODEL SIMULATED DESIGN CAPTURE ZONE EX-1C
- MODEL SIMULATED DESIGN CAPTURE ZONE EX-1D

NOTES:
FAMSL - FEET ABOVE MEAN SEA LEVEL
GPM - GALLONS PER MINUTE
BGS - BELOW GROUND SURFACE

NAD 1983 STATE PLANE
NEW YORK LONG ISLAND FEET

0 500 1,000
SCALE IN FEET

FIGURE 1
MODEL SIMULATED DESIGN PUMPING RATE CAPTURE ZONES
FROST STREET SITES
WESTBURY, NEW YORK

REQUESTED BY:	AJ
DRAWN BY:	NR
DATE:	7/30/2018
PROJECT:	0888820265

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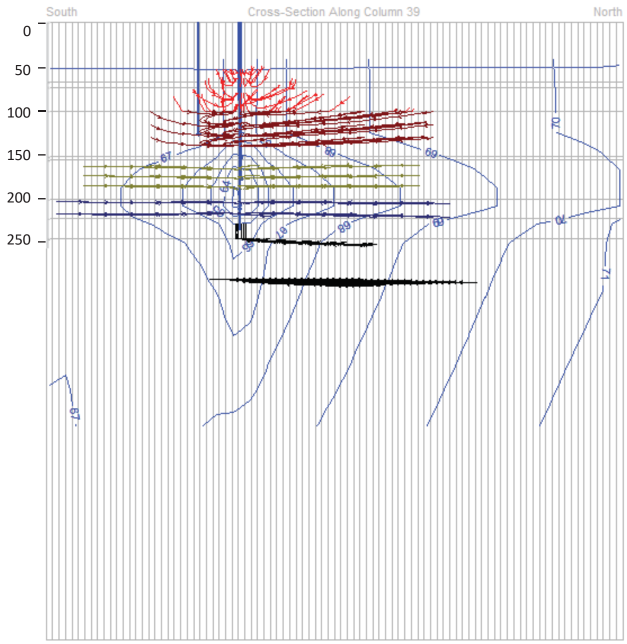
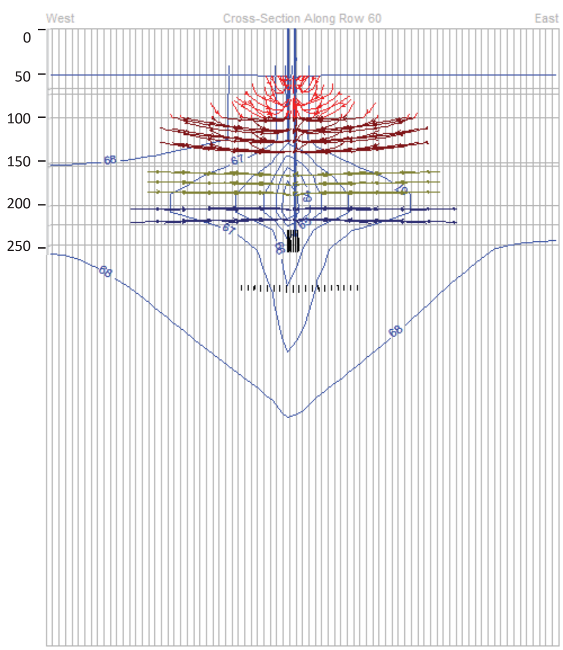
X:\FrostStreet\ModelSimulatedDesignPumpingRateCaptureZone.mxd

DATA SOURCES: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Cross Sections, All Model Layers



Cross section (up- to down-gradient) through EX-1 locations with reverse particle tracks. Groundwater flow is to left.



Cross section (west - east) through EX-1 locations with reverse particle tracks. Groundwater flow is out of page.

Figure 2
Cross Section Across All Model Layers at Design Rates
Frost Street Sites

X:\FrostStreet\ModelSimulatedAlternatePumpingRateCaptureZone.mxd

LEGEND

- GROUP A WELLS - SCREENS 50-80 FAMSL
- GROUP B WELLS - SCREENS 119-149 FAMSL
- GROUP C WELLS - SCREENS 159-184 FAMSL
- GROUP D WELLS - SCREENS 221-249 FAMSL
- DESIGN SHALLOW CAPTURE ZONE (50 TO 150 FEET BGS) (30 GPM) (DASHED WHERE INFERRED)
- DESIGN DEEP CAPTURE ZONE (150 TO 250 FEET BGS) (48 GPM) (DASHED WHERE INFERRED)
- MODEL SIMULATED ALTERNATE CAPTURE ZONE EX-1A1
- MODEL SIMULATED ALTERNATE CAPTURE ZONE EX-1A2
- MODEL SIMULATED ALTERNATE CAPTURE ZONE EX-1B
- MODEL SIMULATED ALTERNATE CAPTURE ZONE EX-1C
- MODEL SIMULATED ALTERNATE CAPTURE ZONE EX-1D

NOTES:
FAMSL - FEET ABOVE MEAN SEA LEVEL
GPM - GALLONS PER MINUTE
BGS - BELOW GROUND SURFACE

NAD 1983 STATE PLANE
NEW YORK LONG ISLAND FEET

0 500 1,000
SCALE IN FEET

FIGURE 3
MODEL SIMULATED ALTERNATE PUMPING RATE CAPTURE ZONES
FROST STREET SITES
WESTBURY, NEW YORK

REQUESTED BY:	AJ
DRAWN BY:	NR
DATE:	7/30/2018
PROJECT:	0888820265

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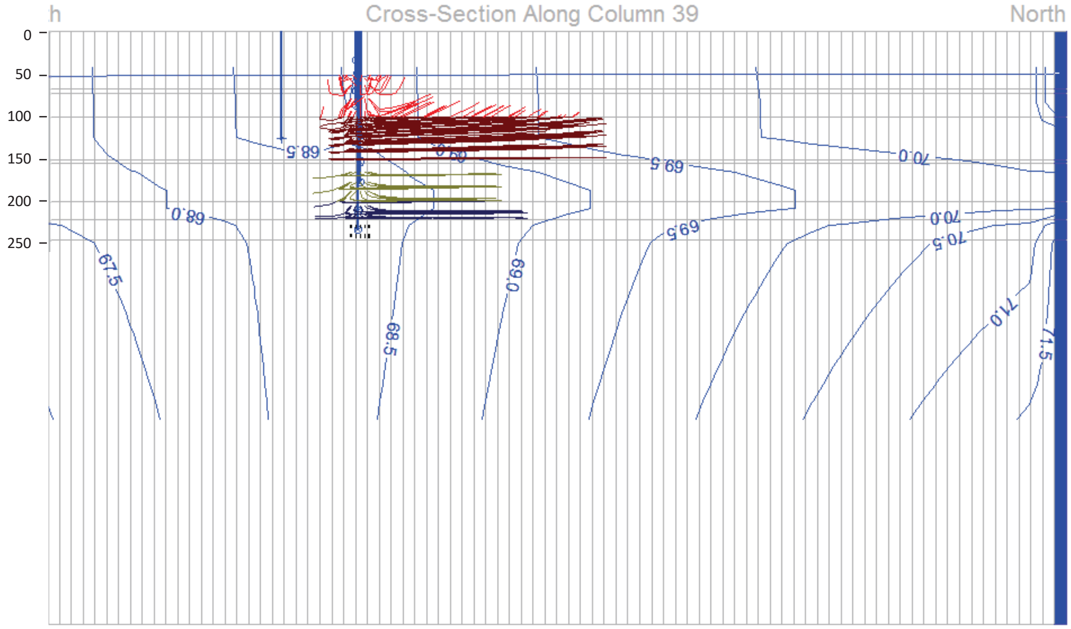
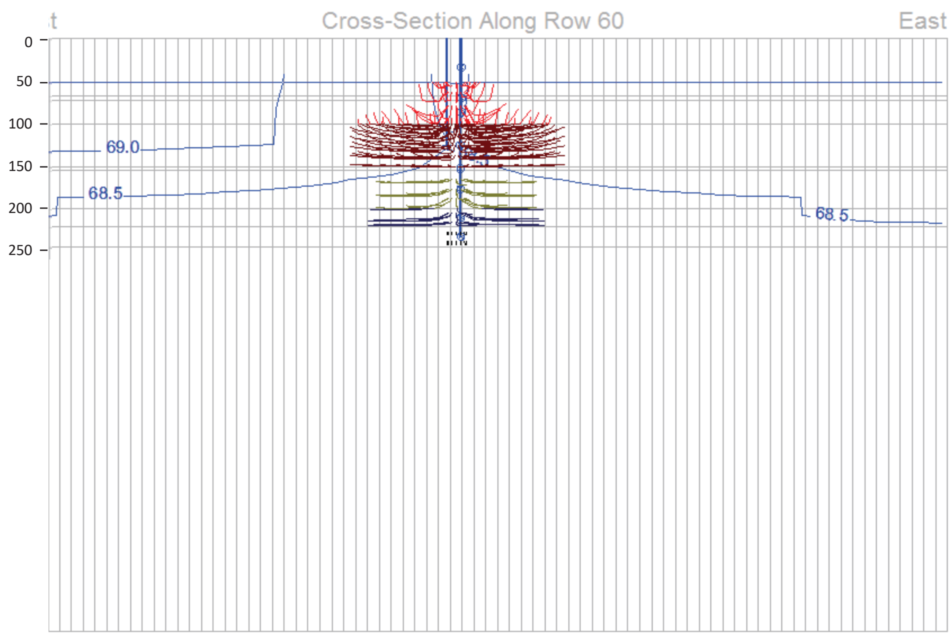
DATA SOURCES: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Cross Sections, All Model Layers



Cross section (up- to down-gradient) through EX-1 locations with reverse particle tracks. Groundwater flow is to left.



Cross section (west - east) through EX-1 locations with reverse particle tracks. Groundwater flow is out of page.

Figure 4
Cross Section Across All Model Layers at Alternate Rates
Frost Street Sites

PUMPING TEST SUMMARY REPORT
GROUNDWATER EXTRACTION / HYDRAULIC CONTAINMENT

FROST STREET SITES
NYSDEC SITE NO. 1-30043 I, L, M
WESTBURY, NEW YORK

EnSafe Project Number:
0888820265

Revision: 0

Prepared for:

Frost Street Parties
Westbury, New York

August 2018

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NEW YORK PROFESSIONAL GEOLOGIST'S SEAL

As a New York-licensed Professional Geologist, I have reviewed and approve this Pumping Test Report and associated groundwater model and seal it in accordance with Article 145 Section 7209 of the New York State Education Laws. In sealing this document, I certify it was prepared under my direction, the geological information contained in it is true to the best of my knowledge and the geological methods and procedures included herein are consistent with currently accepted geological practices.

It is a violation of this law for any person to alter the contained drawings or the report in any way, unless he or she is acting under the direction of a New York-licensed Professional Geologist.

STATE OF NEW YORK
BRIAN E CALDWELL
LICENSED PROFESSIONAL GEOLOGIST
511

Signature

Brian Caldwell
Printed Name

August 10, 2018
Date Signed

000511
New York Professional Geologist License Number

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1.0 INTRODUCTION

In order to finalize the design of the groundwater extraction system at the Frost Street Sites in Westbury, New York, pumping tests and groundwater modeling have been conducted in accordance with the Expanded Pumping Test Supplemental Work Plan (EnSafe, March 7, 2018). This effort was performed to provide a better understanding of the horizontal and vertical flow of groundwater and the capture zone achieved by pumping at a multi-level extraction well cluster located near the downgradient edge of the Frost Street Sites at Old Country Road (Figure 1). The ultimate goal of this effort is to confirm (or select revised) flow rates to achieve the required capture zone as specified in the Remedial Action Work Plan (RAWP) (EnSafe, April 2017).

The site contains a volatile organic carbon (VOC) groundwater plume that a multi-level extraction well cluster located at EX-1 is designed to capture to 250 feet below ground surface (bgs) (Figure 1). The RAWP specified a total pumping rate of approximately 160 gallons per minute (gpm) and a 525 feet wide capture zone for well cluster EX-1 extending 116 feet downgradient of the well (Figure 1). The design capture zone presented in the RAWP was analytically calculated using aquifer parameters from literature and nearby sites, in the absence of site-specific data, and included an added 1.5 design factor to account for uncertainties.

Sampling and well development efforts performed to date at the EX-1 cluster wells (i.e., wells A, B, C, and D) suggest that the groundwater yield and plume concentrations vary vertically. Vertical heterogeneity of the local hydrogeology associated with the aquifer layering and stratification is indicated by the boring and gamma logs completed for EX-1D (deepest well in the cluster); the logs also indicate the presence of several intervals of silt and clay interbedded within the target upper 250 feet of the aquifer. Because of the lateral and vertical heterogeneity in the local aquifer, water levels were monitored in 25 nearby monitoring wells during a variety of pumping test intervals associated with the remedial system startup in late March through early May 2018. A three-dimensional analytical model, Multi Layered Unsteady state (MLU) was used to assess the pumping tests and to determine site-specific parameters for the layered and stratified aquifer (Hemker and Post, 2013). The site aquifer parameters were then in turn used as the initial inputs for a numerical flow model constructed using the modular three-dimensional finite-difference groundwater flow model (MODFLOW) (McDonald and Harbaugh, 1988). The MODFLOW model was constructed using site-specific hydrogeology details and aquifer parameters to evaluate of the source of groundwater and hydraulic capture for the EX-1 wells operating individually and in concert (versus the analytical model previously used for design which utilized broad assumptions an aquifer characteristics). The numerical model solution allows discretization of the effects of pumping each vertical aquifer zone by assigning unique hydraulic properties to each of those zones and provides the best evaluation of the pumping remediation using the site empirical data in the absence of long-term performance monitoring.

The goal of the work documented in this report is to utilize site-specific pumping data generated during several weeks of remedial system operation at design pumping rates to refine the understanding of the site hydrogeology and to construct a three-dimensional numerical model that can be used as a tool to interpret and optimize the hydraulic capture of the plume.

The work described and documented in this report includes the following:

- Summary of the hydrogeology conceptual site model
- Description and analyses of pumping tests performed
- Construction of an updated groundwater flow model
- Assessment of the remedial system capture zone

2.0 HYDROGEOLOGY CONCEPTUAL SITE MODEL

The following subsections describe the occurrence and movement of groundwater at the site based on background information and the most recent site data collection. It is a representation of the hydrogeology information and data, incorporates interpretation and judgement, and attempts to synthesize many variables of a complex system that are not fully known. It is assumed that groundwater flow is the primary force directing the movement and migration of VOCs in groundwater for the area identified as the site plume. As a conceptual model, a measure of uncertainty is fundamental, and as new data become available the conceptualization may need to be updated or altered.

2.1 Site Setting

The site and surrounding topography is relatively flat with a general slope to the south. Well EX-1 and the associated site plume are located in an area has been highly developed and is mostly covered by paved surfaces or large commercial buildings. There are no nearby surface water bodies that directly interact with the local aquifer. Annual precipitation for the area is 48 inches of rainfall and 21 inches of snow. Because of interception of precipitation by building roofs and paved surfaces, a large proportion of precipitation is routed to the storm water system and is not infiltrated to the ground as direct recharge to the water table at the site.

2.2 Recharge

The site area receives an average of 48 inches of rainfall and 21 inches of snow, as previously stated. Previous investigations of the hydrology of Nassau County, in which the site is located, suggest that roughly half of annual precipitation reaches the water table as direct, county-wide recharge from infiltration (Nassau County Department of Public Works, 2005). Because of the significant development of many areas of Nassau County, the areal distribution of that recharge is deemed to be highly variable with most infiltration likely occurring at localized recharge basins. While precipitation is plentiful, consideration of the urban development of the site suggests that much of the precipitation is intercepted by impermeable surfaces and directed to storm sewers and eventually discharged at recharge basins that are not located at the site vicinity. Therefore, it was anticipated that direct recharge from precipitation used in the groundwater flow model would be significantly less than the county-wide average, and a site value would be determined during model calibration.

2.3 Aquifer Description

The boring log for well EX-1D, which is the deepest of the four extraction wells, indicates the local geology from the ground surface to a depth of 245 feet consists of a sequence of predominantly poorly sorted sand underlain by fine sand with interbeds of silt and clay several feet thick. As noted in the boring log descriptions (Appendix A), well graded gravel and sand is present from the ground surface to a depth of about 45 feet bgs; these deposits are representative of glacial outwash known as the Upper Glacial aquifer when saturated (i.e., when below the water table). Below 45 feet bgs to a depth of about 222 feet bgs, the sediments are predominantly poorly graded fine sand with distinct intervals of silt and clay up to about 6 feet thick; these sediments are saturated and represent the upper portion of the Magothy aquifer. The bottom of the EX-1D boring log (222 to 245 feet bgs) indicates the presence of a thick (about 23 feet) interval of silt and clay. This thick silt and clay interval along with several other thinner silt/clay intervals at shallower depths were shown to be present in other site boing logs located upgradient of EX-1 (e.g., FSMW-8 and FSMW-19) and in boring logs for nearby and downgradient sites of investigation (e.g., New Cassel/Hicksville Groundwater Contamination Superfund Site). The natural gamma log for the EX-1D boring is provided in Appendix A; gamma counts per second (cps) greater than about 30 to 40 cps are indicative of the presence of silt and clay intervals in the sedimentary sequence at location EX-1. Based on typical geology for Nassau County, the bottom of the Magothy aquifer may be 600 to 700 feet bgs at the site.

2.4 Groundwater Flow

Water levels for monitoring wells in the vicinity of EX-1 have been monitored historically since late 2006. The local potentiometric surface of the water table in the vicinity of EX-1 has been mapped and presented as figures in previous site monitoring reports. These potentiometric surface maps represent various times and a variety of site conditions. A collection of these figures representing the potentiometric surface in 2007, 2013, 2014, and 2015 and lines annotated on the figures indicating the general groundwater flow direction through the location of EX-1 show azimuths ranging from about 190 degrees to 210 degrees (EnSafe, March 7, 2018). Based on these examples, a representative groundwater flow direction azimuth of 200 degrees was selected (i.e., south 20 degrees west) for representation in the model.

Water level measurements and calculated water table elevations for more current conditions (i.e., 2015 through 2017) for well FSMW-6A, which is located approximately 125 east of EX-1, show the typical depth to the water table ranged from about 45 to 50 feet bgs and the average water table elevation was calculated (i.e., arithmetic mean) to be 71.78 feet above mean sea level (amsl) (EnSafe, March 7, 2018). The average water table elevation for well FSMW-1A that is located approximately 967 feet hydraulically upgradient from FWMW-6A for the same time period was 72.68 feet amsl. The horizontal hydraulic gradient based on these two wells was 0.001 toward the south-southwest. Potentiometric surface mapping of the water table over time shows some variability, but suggests an average water table flow direction of south 20 degrees west.

During the series of pumping tests reported in this document (March to May, 2018), manual measurements of the depth to groundwater in well EX-1A show the elevation of the non-pumping water table ranged from 68.90 to 69.49 feet amsl. These data indicate that the water table occurs at what is interpreted to be the approximate top of the Magothy aquifer for the recorded observations.

2.5 Aquifer Stresses

Two public water supply wells operated by the Bowling Green Water District (wells BG-1 and BG-2) are located approximately 1,620 feet to the south west of EX-1. Based on information posted by the water district, these wells were not operating for the duration of the pumping tests described in this report. As many as nine municipal supply wells operated by the Hicksville, Hempstead, and Westbury water districts are located within about a 2.3 mile radius of the site to the east, southeast, and southwest (as close as approximately 3,800 feet of the site). As will be presented below, operation of one or more of these wells was likely the source of background changes in water levels monitoring at the site during pumping tests.

3.0 PUMPING TESTS

The remedial extraction and treatment system for EX-1 was set up and turned on briefly on March 19 and 20, 2018 to ensure system operation. Electronic data loggers manufactured by Solinst, Inc., were installed in the four-well extraction well cluster (EX-1A, B, C, and D) and 25 monitoring wells at the site on March 19, 2018. The remedial system was then operated for two phases of pumping tests during late March, April, and early through May 2018, as indicated in the Expanded Pumping Test Supplemental Work Plan and water levels in the wells were recorded by the data loggers at 1-minute intervals.

3.1 Testing Summary

The Phase 1 pumping test was performed over the course of two weeks in accordance with the original scope presented in Section 2.12 of the RAWP and the Expanded Pumping Test Supplemental Work Plan. Following the initial shutdown period, each of the four extraction wells were operated, individually (one per day), at design flow rates for 8 hours, and then shut down for a minimum of 16 hours. Following this one week period of individual well testing, all four extraction wells were put in service at design flow rates for one week. Additional details are provided in Table 1.

Phase 2 began, following completion of Phase 1, with the system shut off for one week to ensure aquifer stabilization. After this stabilization period, EX-1A was operated at the design flow rate for one week, then shut down for one week. EX-1B was then operated at the design flow rate for one week, then shut down for one week. Lastly, EX-1A and EX-1B were operated together, at design flow rates, for one week, then shut down. Details of this phase of the test are also provided in Table 1.

Figures 2 and 3 show the pumping rates that were recorded during both phases of pumping tests, respectively. It is noted that Table 1 and Figures 2 and 3 (and all subsequent figures) include test identification numbers (e.g., T1, T2, T3, etc.) that are used to distinguish the tests as discussed in this report; test identification numbers and how they correlate to the Phases and operational wells are provided in Table 1.

As seen in Figures 2 and 3, the pumping rate for each well was consistent with a few short-term fluctuations/interruptions and minor rate changes as noted below.

- Pumping rate decreases were consistently experienced for well EX-1A at the start of each testing period. This well is screened at the water table, and as described below, the well screen crosses a 6-foot thick silt and clay aquitard near its mid-section. This results in a relatively thin saturated zone (about 14 feet thick) on top of the aquitard that dewaters during pumping and reduces the aquifer transmissivity. The result of transmissivity reduction is a decrease in well yield and the pumping rate for EX-1A.

- Abrupt, relatively large, but short-term changes in pumping rates were observed for EX-1A during tests T6 and T8, and for EX-1B during tests T5 and T7. The reasons for the short-term increases in flow rates is not explicitly known. The decreases in pumping rates during tests T6 and T8 were caused by interruptions or pump shut downs associated with system alarms and adjustments.

- The entire remedial system was shut down during T5 on April 6 to re-plum wells EX-1C and D in response to increases in water pH. It is noted that after system restart the pumping rates in those wells were lower for the remainder of T5.

3.2 Water Levels and Drawdown

Water levels were recorded at 1-minute intervals during all pumping tests using electronic data loggers in the four extraction wells and at 25 monitoring wells used as observation wells. The extraction wells EX-1A, B, and C each have 50 feet of screen, and well EX-1D has 40 feet of screen. The extraction wells are clustered within about 25 feet of each other at location EX-1 and the screen depth intervals are vertically sequential, EX-1D being the deepest well. The monitoring wells were installed with 10 foot screen intervals and most locations represent well clusters with multiple screen depths that correspond with one extraction well screen interval. To account for vertical heterogeneity and gradients in the aquifer, the wells were assigned to one of four well groups (A, B, C, or D) consistent with the extraction well depths. Table 2 provides a summary of the well groups and screen depth intervals, well locations and construction information, and the list of wells for each group is sorted according to the geographic distance from reference well EX-1A. The geographic distribution of each well group at the site that contained a data logger is shown in Figure 4. Table 3 provides drawdown for each pumping test determined by subtracting the groundwater elevation (GWE) at the start of pumping from the GWE at or near the end of pumping. Footnotes for Table 3 document the observed drawdown for some well groups during the shot pumping tests (T1 through T4) were not used or adjusted to account for the overwhelming impacts of background water level fluctuations associated with distant aquifer stresses (e.g., supply well pumping) on the observations. Adjustments to the drawdown for the longer, higher-rate pumping tests (T5 through T8) were not attempted and some uncertainty thus noted, particularly for more distant observation wells. Some spurious values are not reported in Table 3.

Each well used for water level observation has been surveyed to provide a ground surface and top of well casing datum for each well. The survey data, a near continuous record of site barometric pressure, and manual readings of the depth to water in each well during each data logger download were used to convert the data logger water level readings into a near continuous record of GWEs for each well. The water level data were used to prepare hydrographs for each well during the Phase 1 and 2 pumping test intervals. Figures 5 and 6 present the hydrographs for each extraction well during Phase I and Phase 2, respectively, and provide informative annotations regarding the pumping well and rates for reach test, identify significant interruptions in pumping, and indicate days on which data loggers were temporarily removed from the wells to download data.

Figures 7 through 10 present hydrographs for the A, B, C, and D groups of monitoring wells, respectively, for Phase 1 of the pumping tests. It is noted that each figure represents the same vertical scale; the wells are listed in the legend in order of increasing distance from EX-1; and a consistent color is used for each cluster well. As shown in Figure 4, well clusters FSMW-13 and FSMW-14 are located downgradient of EX-1, and all other wells are located cross- or upgradient of EX-1. A daily cycle of rising and falling GWEs, most prominently displayed in the deeper C and D wells, is attributed to pumping at one or more distant municipal supply wells. Phase 1 testing included short-term, 8-hour pumping intervals at each individual extraction well (tests T1 through T4) and a 5-day pumping interval for all extraction wells pumping together (test T5). All pumping was conducted at the remedial design rate for each extraction well (Table 1), but as noted above and documented on Figure 2, pumping rates for wells EX-1A, C, and D were slightly lower following the pumping interruption that occurred on April 6 for the duration of test T5. This lowering of the total pumping rate during test T5 is manifested on Figures 7 through 10 as a temporary rise followed by a continuation of the previous downward trend in GWEs for the A and B group wells; the C and D wells show a rise in GWEs followed by a flattening of the prior downward trend. All well groups responded with a general rise in GWEs through the end of test T5 following 2.6 inches of rainfall that fell on April 9.

The areal distribution of drawdown at selected intervals after pumping began for test T5 is shown in Figures 11 and 12 for each group of observation wells (Table 3). Figure 11 (t = 2280 minutes) represents maximum drawdown that occurred before the pumping interruption and subsequent lowering of the total pumping rate that occurred on April 6, and Figure 12 (t = 9932 minutes) represents maximum drawdown that occurred before the end of test T5. Figures 13 and 14 show the interpreted corollary potentiometric surfaces at the start of T5 and for 2280 minutes after pumping began.

Figures 15 through 18 present hydrographs for the A, B, C, and D groups of monitoring wells for Phase 2 of the pumping tests. As noted above, each figure represents the same vertical scale; the wells are listed in the legend in order of increasing distance from EX-1; and a consistent color is used for each cluster well. Due to the longer time of Phase 2 testing, the horizontal axis for these figures is compressed compared to the above figures for Phase 1 testing. Similar to Phase 1, Phase 2 includes two distinct daily cycles of rising and falling GWEs, most prominently displayed in the deeper C and D wells, that is attributed to pumping at one or more distant municipal supply wells. This phase of testing included a 7-day pumping interval for well EX-1A only (test T6), a 7-day pumping interval for well EX-1B only (test T7), and a 7-day pumping interval for wells EX-1A and EX-1B together (test T8). All pumping was conducted at the remedial design rate for each extraction well (Table 1). These figures suggest that pumping of only well EX-1A had a relatively minimal impact in the A group observation wells, with the exception of FSMW-13A, apparently due to impacts from rainfall on April 15 and 16. However, a drawdown trend was observed in all other well groups during T6 (Table 3). Pumping of only well EX-1B is observed to have a relatively greater impact on GWEs and a larger drawdown occurred in all well groups. No impacts related to the pumping of EX-1A and EX-1B together are observed on the figures and drawdown listed in Table 3 for test T8 are negative numbers indicating a general rise in GWEs during this test, again apparently related to rainfall occurring on May 16 through 22.

The areal distribution of maximum drawdown near the end of tests T6 and T7 are shown in Figures 19 and 20 for each group of observation wells (Table 3).

3.3 Aquifer Parameters

Test T5 included operation of extraction wells EX-1A, B, C, and D at design flow rates from April 4 through April 11, 2018. Test T5 was selected for the analysis of aquifer parameters because all wells were operated, no significant rainfall occurred, and the hydrographs provided in Figure 5 and Figures 7 through 10 demonstrate that the extraction wells and most observation wells responded to the pumping in a reasonable and predictable manner. The flow rate for each well is shown in Figure 2 for T5, and as noted above, the pumping was interrupted for system adjustments on April 6 in the late day. Following restart of the system the hydrographs show how GWEs generally responded with a slight increase in elevation or flattening of the elevation trends in response to the lower total pumping rate. For the analysis of T5, the data from the start of test T5 on April 4 through midnight on April 5 (2280 minutes, or 1.6 days after pumping began), when maximum drawdown was reached in all observation wells, was selected to estimate the aquifer parameters.

Analysis of aquifer parameters using the data from test T5 was conducted using MLU software (Hemker and Post, 2013). This software program was selected because it is the only commercially available software known to the author that may be used to analyze three-dimensional transient flow for a "layered" aquifer. A layered aquifer may be described as a stack of layers that all respond to the pumping of a well. These aquifers often consist of a series of alternating aquifers and aquitards and are often referred to as a "multi-aquifer system." In other cases there may be no defined aquitard present, but due to vertical heterogeneity it is import to model the vertical component of flow within the aquifer; these aquifers are often referred to as "layered" or "stratified." Sampling data and well specific capacity analysis for EX-1, and the site boring and gamma logs, show that aquitard layers are present and indicated that vertical flow components are import for the site. The list of MLU model assumptions is provided in Appendices B and C.

The MLU software allows the input of data for each extraction well and each observation well over time since pumping began. Each well is assigned to one or more model layers, the well location and construction are described, the pumping interval and rate are input, and the drawdown verses time since pumping began for all, or selected, drawdown observation points are used as the targets for the aquifer parameter estimation process. The analysis begins with conceptualizing the aquifer system of interest; this generally consists of prescribing the simplest conceptual model that is consistent with the site data and observed drawdowns. Thus, the physical nature of the site's aquifer system is conceptualized and an initial set of aquifer parameters are selected to be as representative of the local hydrogeology as possible. A schematic diagram of the conceptual model is provided in Appendix B. The initial MLU model with estimated aquifer parameters for the site is shown in Appendix C, Figure C-1. It is noted that only the aquifer layers are assigned numbers in the MLU model (aquifers, aquitards, and vertical resistance layers are named in the far right column). Because a water table exists at the site, a special, very thin uppermost aquifer layer is provided in the model and assigned a low horizontal conductivity to represent predominantly vertical flow with little horizontal flow across this boundary condition; this layer is underlain by a zero-thickness vertical resistance layer that accommodates vertical flow. The site boring/gamma logs show the aquifer layers to consist of predominantly sand and gravel above the water table and poorly sorted sand for the lower aquifer layers. The presence of relatively thin silt and clay zones (4 to 6 feet) shown on the logs were deemed to be laterally persistent across the site at depths of about 67 and 151 feet bgs and are included in the model as aquitards 1 and 2 (note that elevations are used in the MLU model with a ground surface = 120 feet amsl). Near the bottom of the deep EX-1D borehole, at a depth of about 222 feet bgs, a thick laterally persistent silt and clay zone was identified as aquitard 3 with a thickness of 23 feet. The Magothy aquifer in the area of the site is known to be several hundred feet thick and consist of relatively conductive sandy materials; the aquifer below the deepest boring log at the site is represented consistent with this general description in the MLU model.

The final step for the MLU model is aquifer parameter estimation using the built-in least squares solution. This is an iterative process wherein the optimize function of MLU is used to determine the fit between the observed and simulated drawdowns, the results are scrutinized for plausibility and consistency with the site conceptual model, and the process is repeated until a best fit match between the observed drawdown and model simulated drawdown for a minimal sum of squares residual is reached to the satisfaction of the modeler. The final data fit and the associated aquifer parameter results for the site conceptual model using all observation wells is provided in Appendix C, Figure C-2. The final results for the site conceptual model using only observation wells located less than 300 feet from EX-1 is shown in Appendix C, Figure C-3. The latter approach was deemed more representative because it eliminates distant observations and reduces impacts on the analysis from background aquifer stresses that have greater impact on the smaller drawdown realized at more distance observation well locations.

4.0 GROUNDWATER FLOW MODEL

The flow of groundwater in the Magothy aquifer below the site was simulated using MODFLOW, a widely accepted, three-dimensional, numerical modeling program developed by the USGS (McDonald and Harbaugh, 1988). MODFLOW is a modular, cell-centered, finite difference program that simulates saturated groundwater flow for a wide variety of physical and hydraulic settings. This model was chosen because it provides for the following site-related properties:

- Unconfined and confined aquifer conditions to represent the water table and deeper Magothy aquifer zones of interest
- Provides a three-dimensional framework to represent lateral and/or vertical changes (i.e, homogeneous/heterogeneous, isotropic/anisotropic) in hydraulic properties of the Magothy aquifer
- Provides the groundwater flow basis for conducting particle tracking

Several assumptions were made in the model construction to simulate steady-state groundwater flow across the site, as listed below:

- Because the local topography and the sedimentary layers representing the subsurface hydrogeology are relatively flat within the area of the model domain, the ground surface and all model layers were assumed to be flat. An elevation of 120 feet amsl was used for the ground surface.
- The local elevation of the top of the Magothy aquifer is considered equivalent to the water table at the site; however, the bottom elevation of the aquifer locally is not known. Considering the extraction pumping rates specified in the remedial design for wells EX-1A, B, C, D (i.e., 30 to 48 gpm) and the presence of a thick aquitard below EX-1D, the influence of pumping is not expected to extend significantly below the lower-most screen interval of well EX-1D (i.e., 240 feet bgs). The Magothy aquifer is known to be several hundred feet thick in Nassau County; the bottom of the aquifer was placed at 700 feet bgs in the model.
- Aquifer properties were assumed to be laterally homogeneous and isotopic. The initial aquifer properties for the model were determined from the MLU model analysis of pumping test T5 (as discussed in Section 3.3 and Appendix C).

- Aquifer storage properties were specified based on the MLU model results, but are not required for the steady-state flow model. Aquifer porosity was required for the model to simulate groundwater flow velocity and to support particle track modeling. Site-specific analysis of aquifer porosity is not available. A bulk effective porosity of 0.2 was assumed for all model layers to represent the predominantly fine sand described for the Magothy aquifer (i.e., below depth of about 45 feet) in the EX-1D boring log (SP and SW USCS soil classifications on boring log). This value was selected as the default for USCS soil classifications SP and SW used by the U.S. EPA for time of travel calculations (U.S. EPA, 1989).

- The current steady-state groundwater flow direction and hydraulic gradient were assumed to be accurately represented by multiple rounds of water level measurements collected at the site from 2007 to 2017. GWEs based on water levels recorded by data loggers at the site on March 25, 2018, prior to conducting the pumping tests, were consistent with historic data and were used to represent current steady-state conditions for model calibration.

Particle track modeling to simulate the path lines of groundwater flow to well EX-1 under various pumping configurations was conducted using MODPATH (Pollock, 1989). MODPATH uses flow information generated by MODFLOW to simulate advective groundwater movement and generates particle path lines to visualize the results. It is assumed that the contaminants of interest migrate through the aquifer at the same rate and direction as groundwater, that is, no retardation, dispersion or degradation of the chemical contaminants in the aquifer are simulated.

MODFLOW and MODPATH were implemented using Groundwater Vistas (Version 6) software licensed by Environmental Solutions, Inc. (Environmental Solutions, Inc., 1999).

4.1 Model Domain and Grid

The size and shape of the model domain for the site area is shown in Appendix D, page D-1. Based on the average groundwater flow direction in the area of EX-1 under non-pumping conditions (as discussed in Section 2.4) the model domain was rotated north 20 degrees east so that the model Y-axis would be parallel with the direction of groundwater flow (south 20 degrees west). The model grid consists of 50 by 50 foot cell-centered nodes arranged in 90 rows and 80 columns. The domain is 4,500 feet in the direction parallel with groundwater flow (south 20 degrees west). Well EX-1 is located approximately 1,500 feet from the downgradient and 3,000 feet from the upgradient domain boundaries. The domain is 4,000 feet wide, perpendicular to groundwater flow, with well EX-1 located approximately in the middle of the domain. Vertically the model is represented by 9 layers for a total of 64,800 cells; all cells are active (Appendix D, page D-1). The model domain dimensions were selected with consideration of the pumping rates to be simulated such that the horizontal boundary heads were unlikely to be significantly impacted by the pumping at the EX-1 location.

4.2 Boundary Conditions and Layers

The model boundaries are aligned with the model domain and define the flow conditions for the groundwater within the domain. There are no natural groundwater divides or boundary conditions in the vicinity of the area of interest; therefore, the up- and downgradient boundaries were set as constant heads representing the steady-state water table potentiometric surface. The elevation of the up- and downgradient boundaries were based on the regional gradient and flow direction for the Magothy aquifer as discussed in Section 2.4 above. Using a gradient of 0.001, an observed groundwater elevation of 68.85 feet amsl at EX-1, and the distance from EX-1, the upgradient constant head boundary was set to 71.7 feet amsl and the downgradient constant head boundary was set to 67.6 feet amsl. The up- and downgradient boundary elevations therefore represent potentiometric surfaces contours located about 3,000 feet upgradient and 1,500 feet downgradient of EX-1. The remaining two side boundaries are aligned essentially parallel to groundwater flow through the model domain and were therefore set as no-flow boundaries (Appendix D, pages D-1 and D-2).

Model layers were defined according to the aquifer conceptual model and aquifer pumping test analyses (Appendix B). Layers 1, 3, 4, 6, and 7 represent sand-dominated aquifer layers with variable properties; layers 2, 5, and 8 are low conductivity aquitard zones logged as silt and clay; and layer 9 was included to represent the remainder of the Magothy aquifer beneath aquitard 3. As noted above in Section 3.3, pumping test analyses using the MLU model showed a range of results demonstrating vertical heterogeneity in the local aquifer parameters. Appendix D, pages D-2 and D-3 provide profile views of the model showing the model layers (Appendix B). Initial Layer properties taken from pump test T5 analyses are summarized below:

Model Layer	Thickness (feet)	Elevation Top (feet amsl)	Elevation Bottom (feet amsl)	Initial Kx,y (feet/day)	Initial Kz (feet/day)	Initial Storage Sy, Ss^{-ft}	Porosity (decimal)
1	67	120	53	0.98	2.54	0.2	0.2
2	6	53	47	1.6	1.6	1.70E-05	0.1
3	27	47	20	7.65	29.81	1.10E-05	0.2
4	51	20	-31	52.89	29.81	6.00E-06	0.2
5	4	-31	-35	0.58	0.58	2.50E-05	0.01
6	45	-35	-80	26.57	15	6.80E-06	0.2
7	22	-80	-102	34.95	15	1.40E-05	0.2

Model Layer	Thickness (feet)	Elevation Top (feet amsl)	Elevation Bottom (feet amsl)	Initial Kx,y (feet/day)	Initial Kz (feet/day)	Initial Storage Sy, Ss^{-ft}	Porosity (decimal)
8	23	-102	-125	0.003	0.003	4.30E-06	0.05
9	455	-125	-580	50	25	6.00E-07	0.2

Kx, Ky – horizontal hydraulic conductivity in X and Y direction (Table 2)
Kz – vertical hydraulic conductivity
Ne – effective porosity
Shading indicates model layer is an aquitard.

4.3 Model Calibration

The groundwater flow model for the site area presented herein represents an estimation based on steady-state conditions and homogeneous/isotopic conditions for each model layer; the model system is believed to be representative of site conditions and a tool that can reasonably simulate future site conditions (e.g., EX-1 groundwater capture zones). Physical and hydraulic properties of the aquifer zones of interest were assigned based on analysis of site-specific pumping test data, but some initial properties were assigned based on plausible values from published literature for similar aquifer materials and site conditions at nearby sites on Long Island, New York. The United States Geological Survey (USGS) notes that "hypothetical models have been used to examine various processes that affect or are affected by ground-water flow, for example: boundary conditions, contributing areas to wells, and model calibration" (USGS, 2004).

The primary goal for model calibration was achievement of a simulated water table potentiometric surface consistent with the flow direction, hydraulic gradient, and water table elevation described in the above sections for steady-state conditions in the area of EX-1 and that shows low statistical residuals for GWEs observed on March 25, 2018 compared to simulated GWEs at 29 target observation and extraction wells. This calibration was achieved using the PEST (Doherty, 2005) inverse calibration model to determine the model sensitivity of the up- and downgradient constant heads at the model domain boundaries, sensitivity of the aerial recharge to the aquifer, and sensitivity of aquifer properties for hydraulic conductivity (Kxy, Kz) and storage (Ss, Sy). The sensitivity analysis was used to select parameters for adjustment and the calibration process is presented on Appendix D, pages D-4 through D-16. The final data-fit and calibration statistics are presented on Appendix D, pages D-15 and D16. The final statistics show a low residual sum of squares (0.121 feet) and low root mean square (RMS) ERROR (0.07 feet), and the scaled RMS (0.076) is less than 10 percent of the range of GWEs used as targets (excluding well FSMW-8A in model layer 1) that is generally considered a good calibration statistic. Appendix D, page D-2 shows the calibrated model simulated steady-state potentiometric surface for model layer 1 (water table) and up- and downgradient cross sections.

The final MODFLOW model layer properties as adjusted during calibration are summarized below:

Model Layer	Thickness (feet)	Elevation Top (feet amsl)	Elevation Bottom (feet amsl)	Initial Kx,y (feet/day)	Initial Kz (feet/day)	Initial Storage Sy, Ss-ft	Porosity (decimal)
1	67	120	53	0.98	2.54	0.0044	0.2
2	6	53	47	1.6	1.6	1.70E-05	0.1
3	27	47	20	7.65	29.81	1.10E-05	0.2
4	51	20	-31	52.89	29.81	6.00E-06	0.2
5	4	-31	-35	0.58	0.00063	2.50E-05	0.01
6	45	-35	-80	26.57	15	6.80E-06	0.2
7	22	-80	-102	34.95	15	1.40E-05	0.2
8	23	-102	-125	0.003	0.003	4.30E-06	0.05
9	455	-125	-580	50	25	6.00E-07	0.2

Kx, Ky — horizontal hydraulic conductivity in X and Y direction (Table 2).
Kz — vertical hydraulic conductivity
Ne — effective porosity
Shading indicates model layer is an aquitard.

5.0 EXTRACTION WELL GROUNDWATER FLOW AND CAPTURE ZONE ASSESSMENT

The calibrated flow and particle tracking models were used to assess the impacts of two extraction scenarios: 1) design pumping rates as specified in the RAWP and 2) an alternative extraction scenario selected to meet the required capture zone in the RAWP but also minimize the amount of uncontaminated water captured and processed via the treatment system. The capture zones created for both scenarios in all target aquifer layers are compared to the design capture zone presented in the RAWP to demonstrate that the required design capture zone dimensions are met.

Based on the site hydrogeologic conceptual model, flow model construction, and the screen intervals of extraction well EX-1, the particles were placed and tracked in the following model layers for simulation of the capture zones (Appendix B):

Well	Screen Depth feet bgs	Model Layers
EX-1A	50-100	1 and 3
EX-1B	100-150	4
EX-1C	150-200	6
EX-1D	200-240	7

The particle tracking for each scenario included particle starting locations at multiple, equally spaced, vertically-stacked rings of particles (each ring containing 12 particles) at a radial distance of 40 feet from the well screen for each model layer that was pumped (see above). The particles were tracked backward in time for a sufficient amount of time to define the shape of the capture zone, based on the scenarios as describe above, to their point of origin in the aquifer. A plan view of the particle traces for each target aquifer layer and two cross section views of the particle traces are provided for each scenario in Appendix E; arrows are displayed along each particle trace at two-year intervals. The design capture zone from the RAWP is also shown for reference on each plan view figure for reference (green line). The north-south cross section provided for each scenario shows model column 20 that represents a groundwater flow line through EX-1 (i.e., up- to downgradient); the west-east section shows the model row that passes through the well perpendicular to the groundwater flow line. It is also noted that particles have a unique color for each model layer, and a given particle will change color if it passes from layer to layer vertically.

5.1 Design Pumping Scenario

The design pumping scenario simulates wells EX-1A and EX-1B pumping at 30 gpm each and wells EX-1C and EX-1D pumping at 48 gpm each under steady-state flow conditions. Appendix E, pages E-1 through E-3 provide a sequence of figures from the model showing the simulated pumping potentiometric surface and backward tracked particle traces for each target aquifer layer. It is noted that well EX-1A is screened across two model aquifer layers (model layers 1 and 3) separated by an interbedded aquitard layer (model layer 2); therefore, model layers 1 and 3 represent the capture zones simulated for EX-1A (A1 and A2, respectively).

To estimate the extent of the capture zone created by the pumping in each layer the outline of the particle traces was annotated on each figure to show the limits of capture from the downgradient stagnation point (local groundwater divide during pumping) and laterally to each side of EX-1 to show the width of capture. For model layer 1 that represents a relatively thin (14 feet thick) perched water table aquifer (i.e., capture zone EX-1 A1) it is noted that capture is dominated by a strong downward flow component through the thin aquitard into model layer 3 wherein flow becomes predominantly horizontal to well EX-1A. Thus, lateral particle traces do not appear for model layer 1.

The dimensions of the model simulated capture zones for each layer are summarized in Table 4 along with the design capture zone dimensions for comparison. Figure 21 provides a plan view summary of the model simulated design pumping capture zones on the site map. The design pumping scenario shows that the capture zones created by this pumping scheme result in capture zones much larger than required by the design capture zone of the RAWP.

5.2 Alternate Pumping Scenario

The model was used iteratively to simulate various pumping well combinations and rates to find a pumping scheme that produces capture zones consistent with the dimensions of the design capture zone and thus minimize the capture of uncontaminated groundwater. The analysis showed that pumping EX-1A at 15 gpm and EX-1C at 8 gpm met the alternate scenario objectives (i.e., the design capture zone). Appendix E, pages E-4 through E-6 provide a sequence of figures from the model showing the simulated pumping potentiometric surface and backward tracked particle traces for each target aquifer layer. As above, well EX-1A is screened across two model aquifer layers (layers 1 and 3) separated by an interbedded aquitard layer (model layer 2); therefore, model layers 1 and 3 represent the capture zones simulated for EX-1A (A1 and A2, respectively).

To estimate the extent of the capture zone created by the pumping in each layer the outline of the particle traces was annotated to show the limits of capture downgradient from the downgradient stagnation point and laterally to each side of EX-1 to show the width of capture. As above, model layer 1 that represents a relatively thin (14 feet thick) perched water table aquifer (i.e., capture zone EX-1 A1) is dominated by a strong downward flow component through the thin aquitard into model layer 3 wherein flow becomes predominantly horizontal to well EX-1A. Thus, lateral particle traces do not appear for model layer 1.

The dimensions of the model simulated capture zones for each layer are summarized in Table 4 along with the design capture zone dimensions for comparison. Figure 22 provides a plan view summary of the model simulated alternate pumping capture zones on the site map. The alternate pumping scenario shows that the capture zones created by this pumping scheme result in capture zones consistent with those required by the RAWP and that reduce the volume of water captured.

5.3 Recommendations

These modeling efforts have concluded that the design pumping scenario yields capture zones much larger than required by the design capture zone of the RAWP. It is recommended that the alternate pumping scenario described above be utilized in order to effectively remediate the groundwater plume while minimizing the amount of uncontaminated water that is unnecessarily removed and treated.

6.0 REFERENCES

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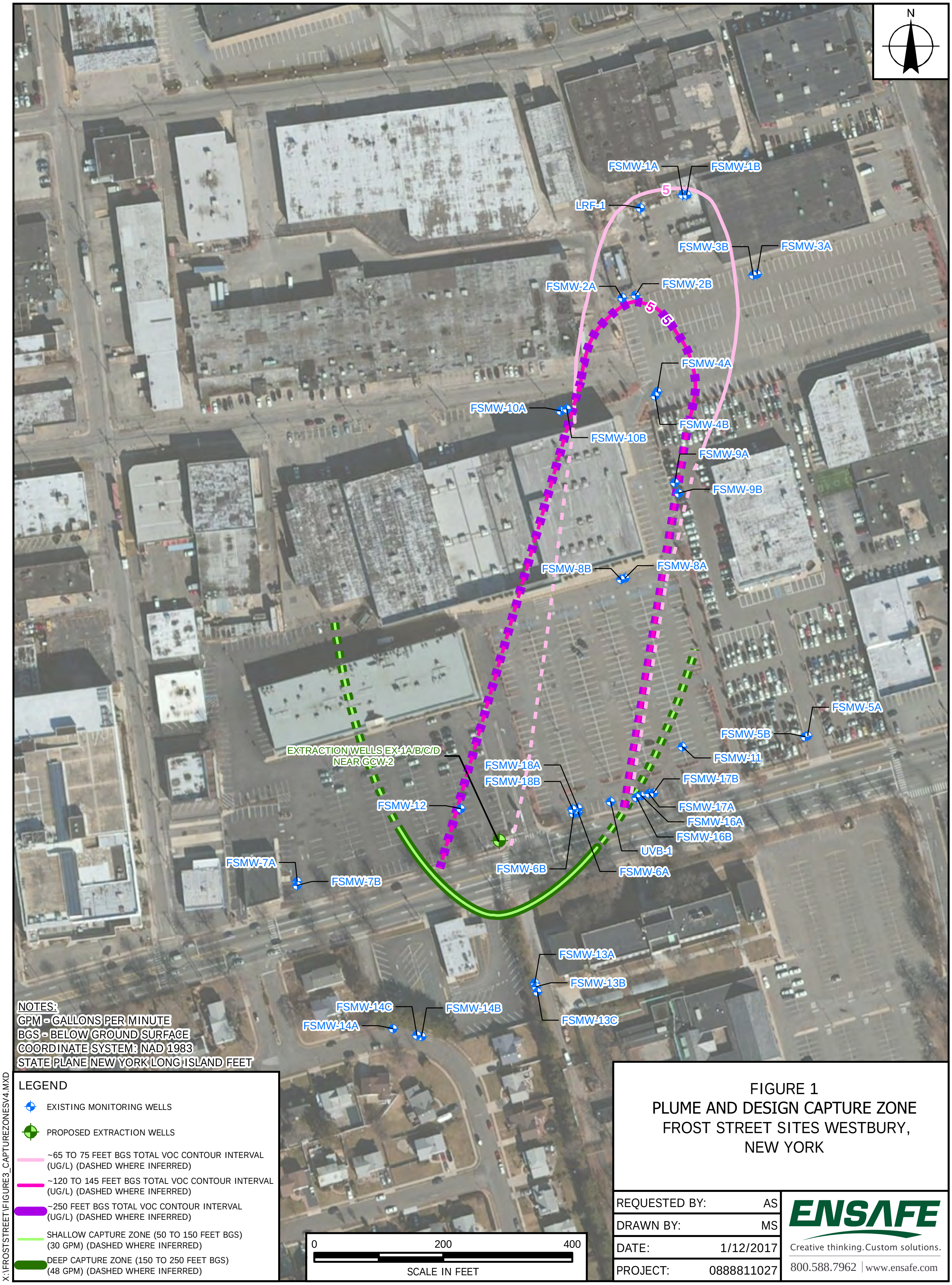
Figures



DATA SOURCES: SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY

Figure 2. Phase 1 Pumping Tests Flow Rates

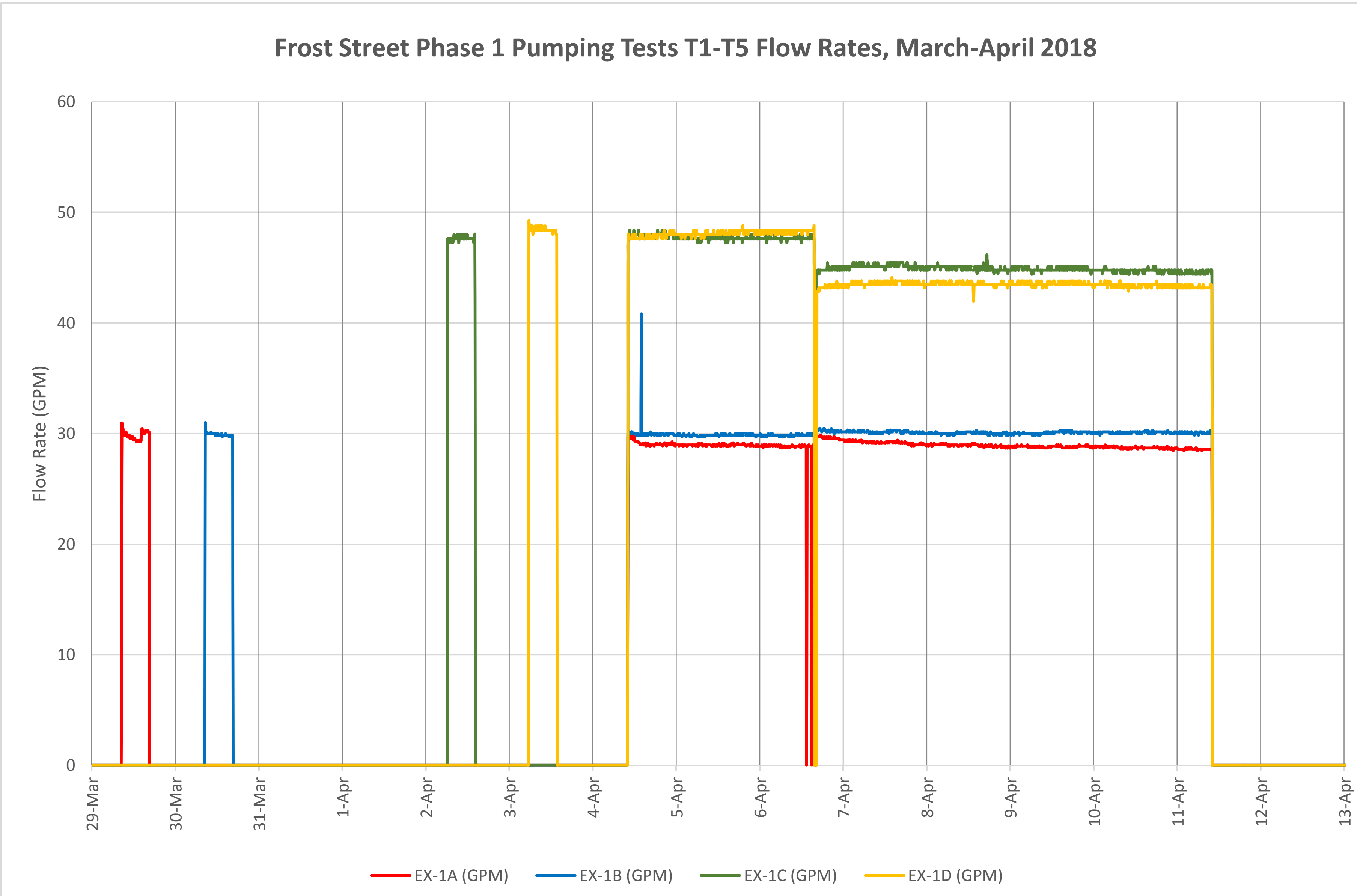
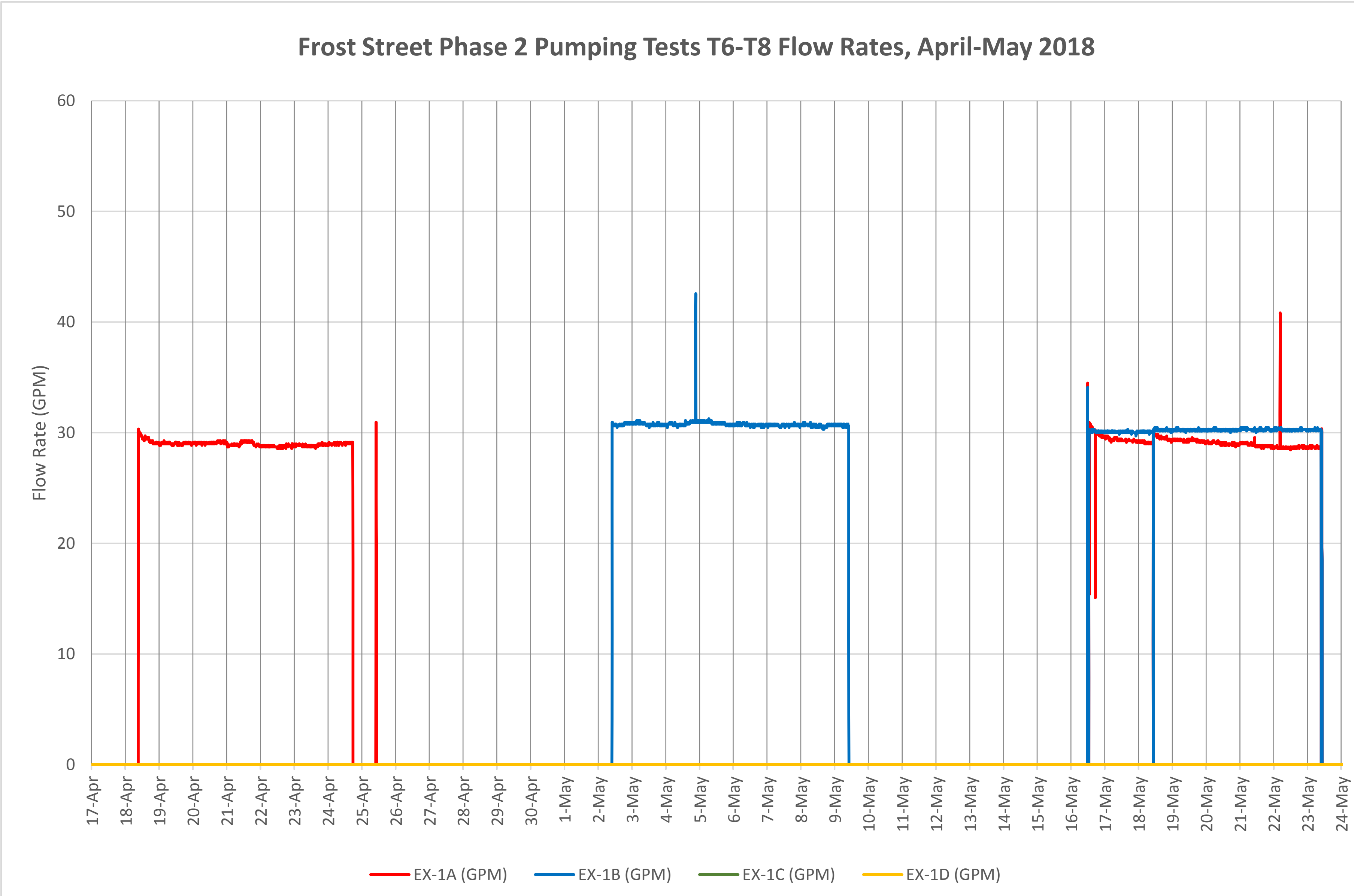


Figure 3. Phase 2 Pumping Tests Flow Rates



System Operational Data (atj-2).xlsx P2 Rates 7/20/2018

FIGURE 4
WELL SCREEN GROUP INTERVALS
FROST STREET SITES WESTBURY,
NEW YORK

LEGEND

- EXTRACTION WELL
- MONITORING WELL
- SHALLOW CAPTURE ZONE (50 TO 150 FEET BGS) (30 GPM) (DASHED WHERE INFERRED)
- DEEP CAPTURE ZONE (150 TO 250 FEET BGS) (48 GPM) (DASHED WHERE INFERRED)

NOTES:
- GPM = GALLONS PER MINUTE
- BGS = BELOW GROUND SURFACE
- RED = GROUP A, 50-80 SCREEN DEPTH INTERVAL
- BLUE = GROUP B, 119-149 SCREEN DEPTH INTERVAL
- GREEN = GROUP C, 159-184 SCREEN DEPTH INTERVAL
- PURPLE = GROUP D, 221-249 SCREEN DEPTH INTERVAL

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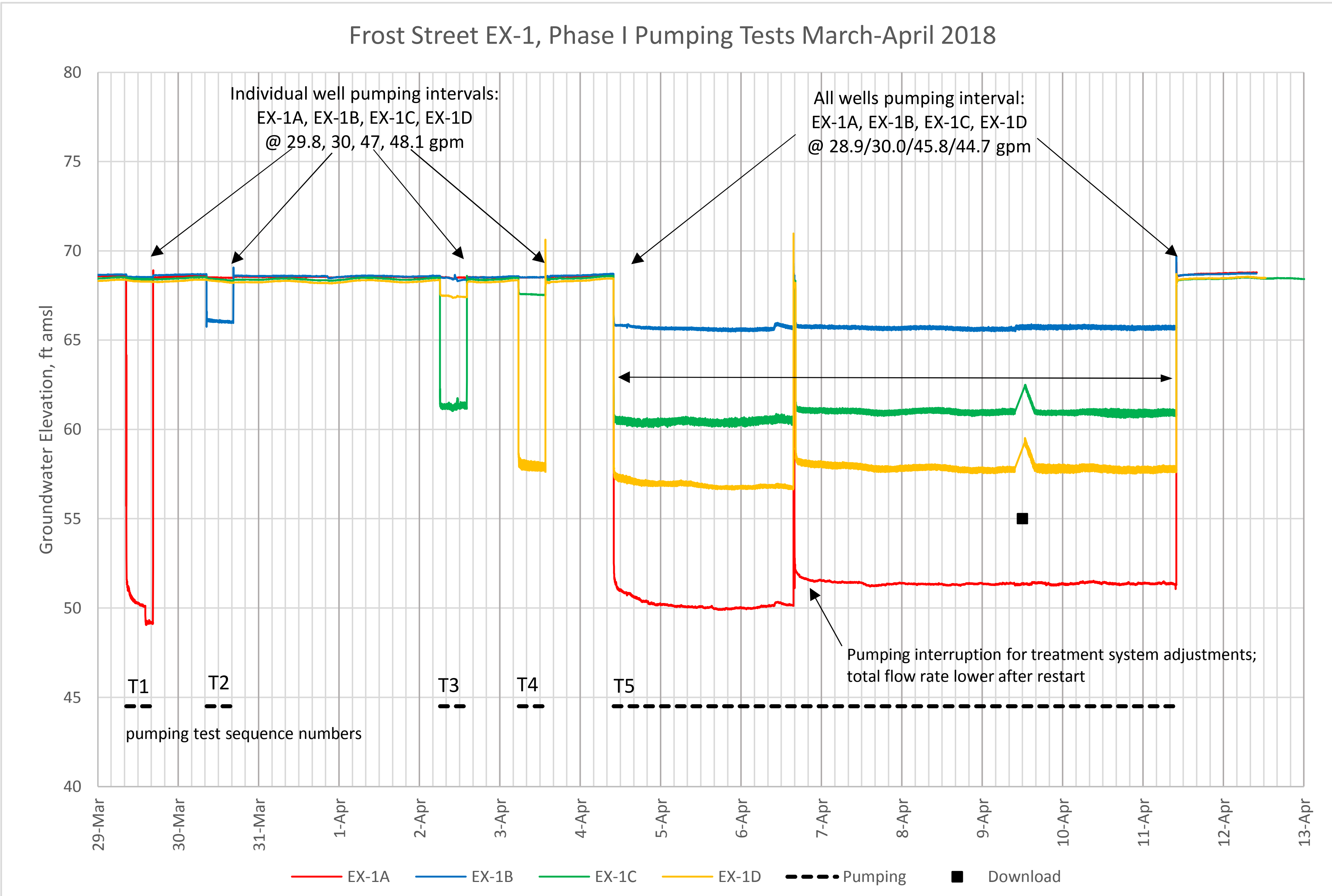
Figure 5. Phase 1 Extraction Well Hydrographs



FSPT hydro.xlsx P1 7/23/2018

Figure 6. Phase 2 Extraction Well Hydrographs

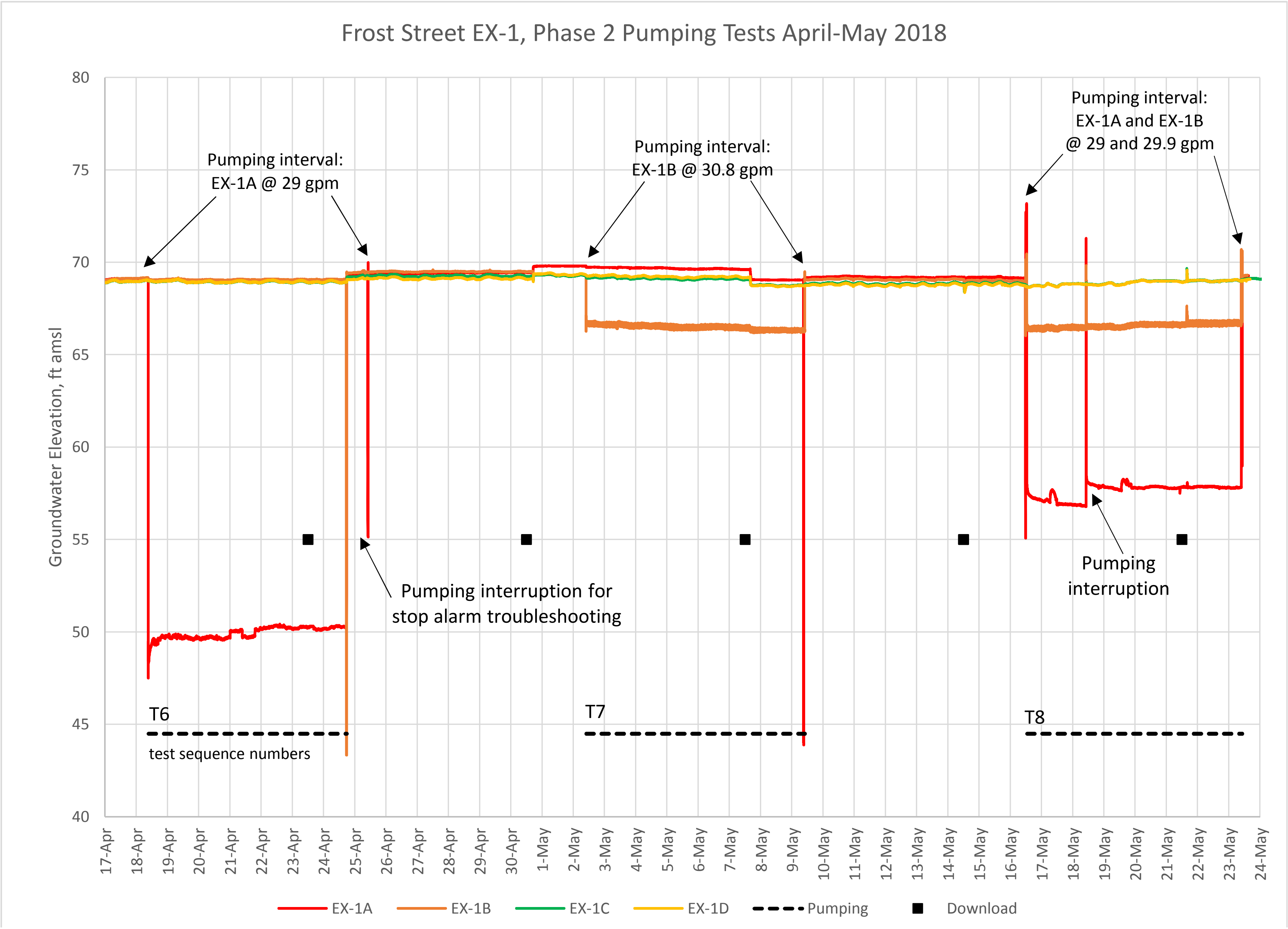


Figure 7. Phase 1 Group A Observation Well Hydrographs

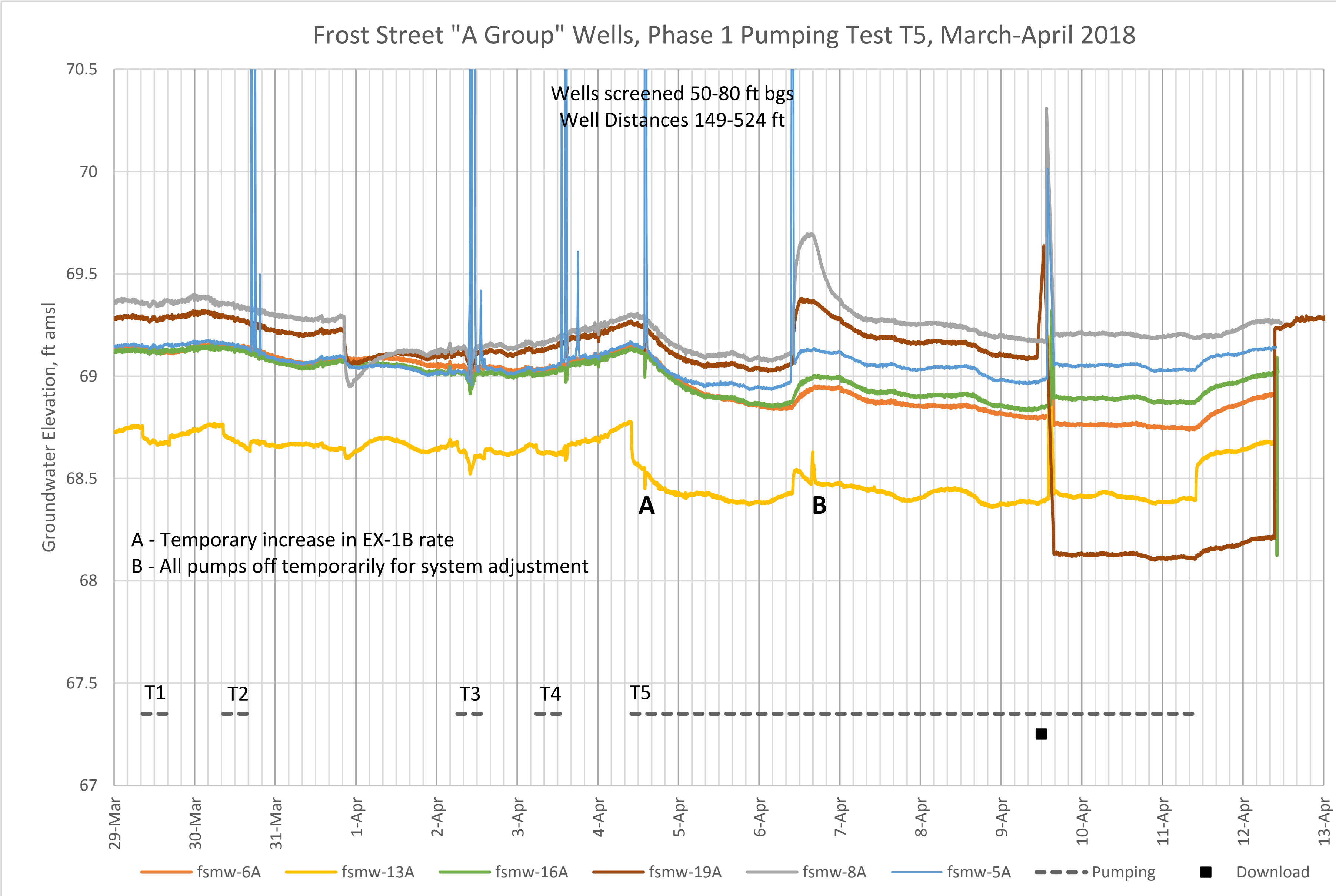


Figure 8. Phase 1 Group B Observation Well Hydrographs

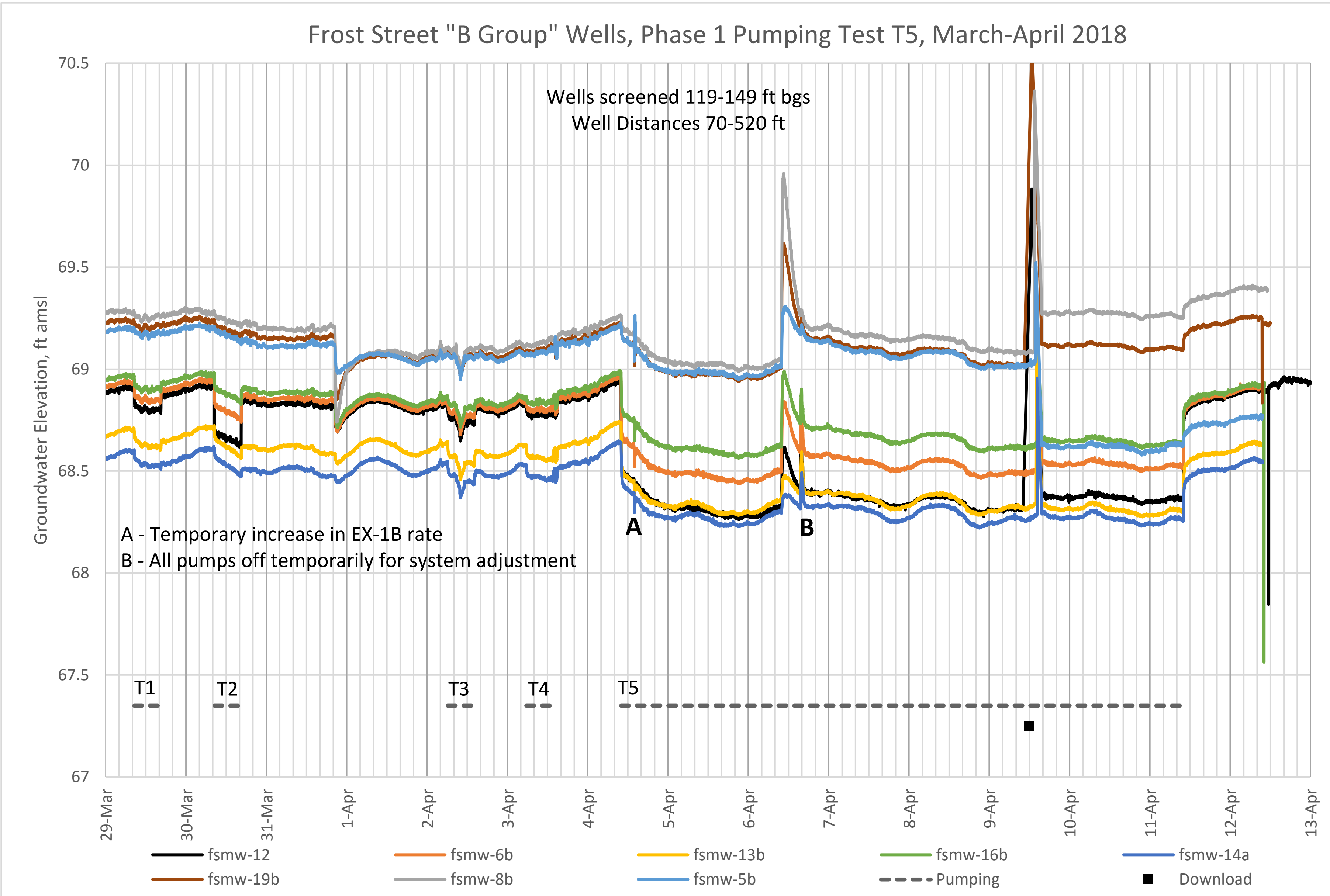


Figure 9. Phase 1 Group C Observation Well Hydrographs

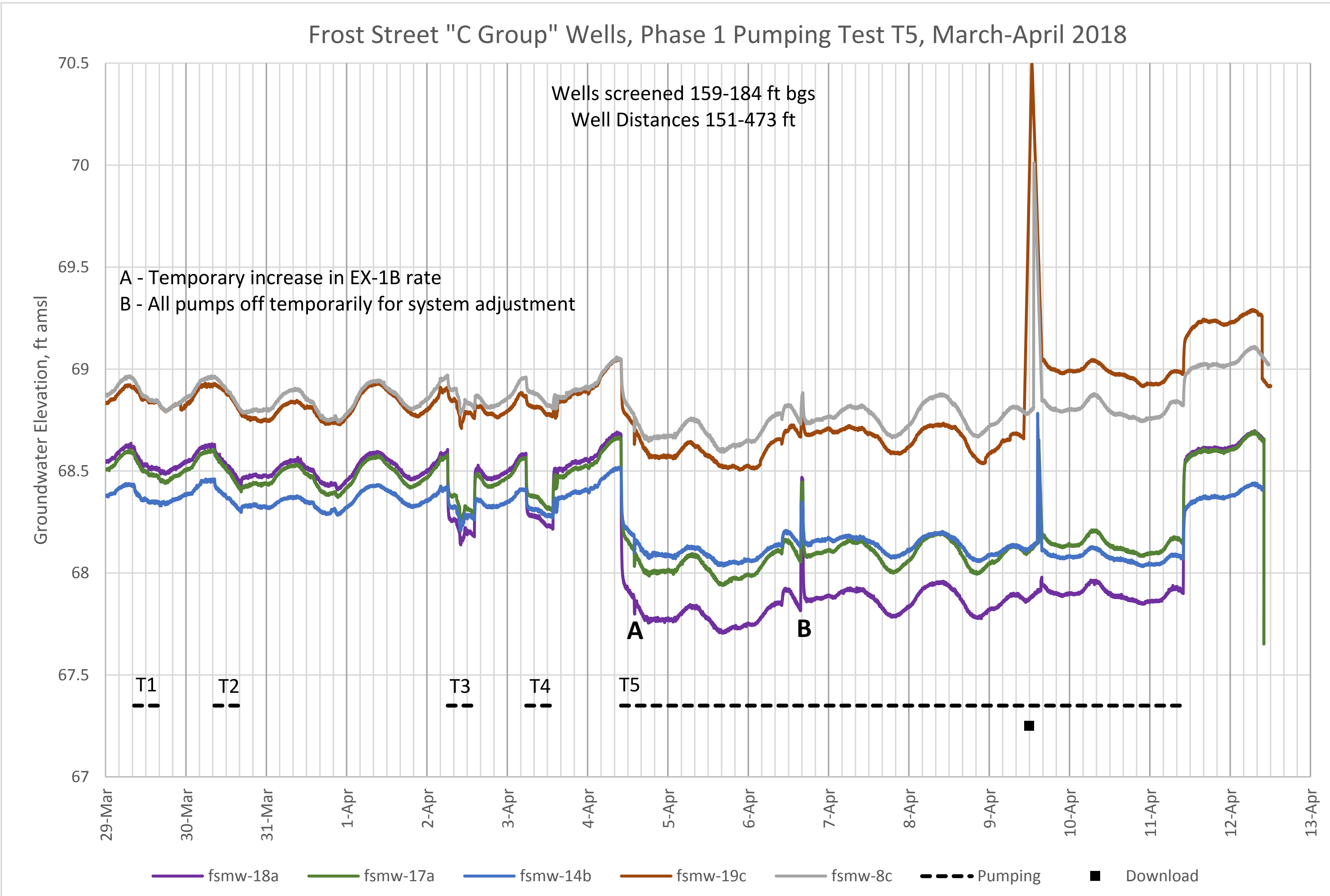


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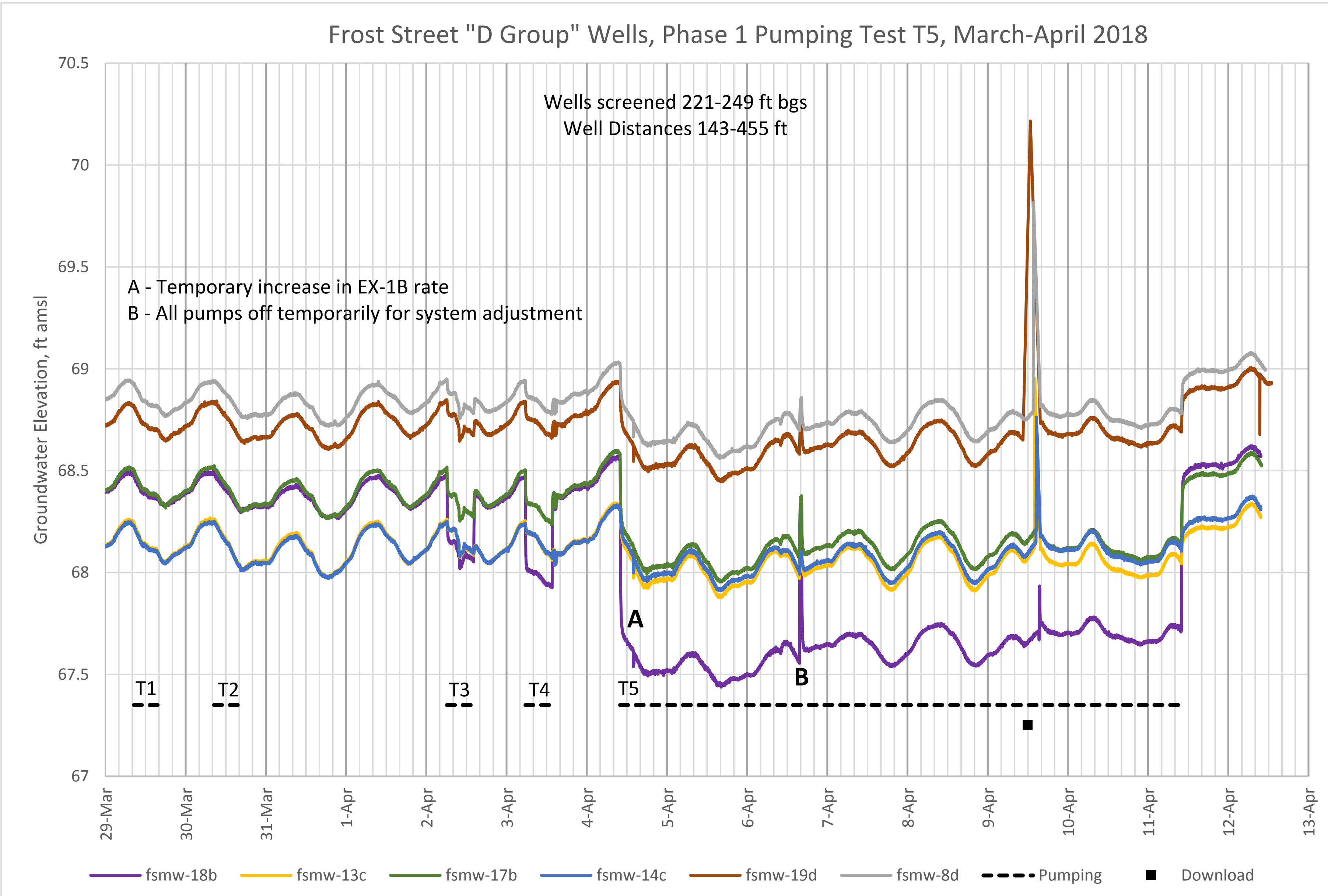
Figure 10. Phase 1 Group D Observation Well Hydrographs



FSPT hydro.xlsx T5D 7/23/2018

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LEGEND

- GROUP A WELLS - SCREENS 50-80 FAMSL
- GROUP B WELLS - SCREENS 119-149 FAMSL
- GROUP C WELLS - SCREENS 159-184 FAMSL
- GROUP D WELLS - SCREENS 221-249 FAMSL
- SHALLOW CAPTURE ZONE (50 TO 150 FEET BGS) (30 GPM) (DASHED WHERE INFERRED)
- DEEP CAPTURE ZONE (150 TO 250 FEET BGS) (48 GPM) (DASHED WHERE INFERRED)

NOTES:
FAMSL - FEET ABOVE MEAN SEA LEVEL
GPM - GALLONS PER MINUTE
BGS - BELOW GROUND SURFACE

FIGURE 11
WATER LEVEL DRAWDOWN, TEST 5
2280 MINUTES AFTER PUMPING BEGAN
4/6/18 0:00
FROST STREET SITES
WESTBURY, NEW YORK

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LEGEND

- GROUP A WELLS - SCREENS 50-80 FAMSL
- GROUP B WELLS - SCREENS 119-149 FAMSL
- GROUP C WELLS - SCREENS 159-184 FAMSL
- GROUP D WELLS - SCREENS 221-249 FAMSL
- SHALLOW CAPTURE ZONE (50 TO 150 FEET BGS) (30 GPM) (DASHED WHERE INFERRED)
- DEEP CAPTURE ZONE (150 TO 250 FEET BGS) (48 GPM) (DASHED WHERE INFERRED)

NOTES:
FAMSL - FEET ABOVE MEAN SEA LEVEL
GPM - GALLONS PER MINUTE
BGS - BELOW GROUND SURFACE

FIGURE 12
WATER LEVEL DRAWDOWN, TEST 5
9932 MINUTES AFTER PUMPING BEGAN
4/11/18 7:30
FROST STREET SITES
WESTBURY, NEW YORK

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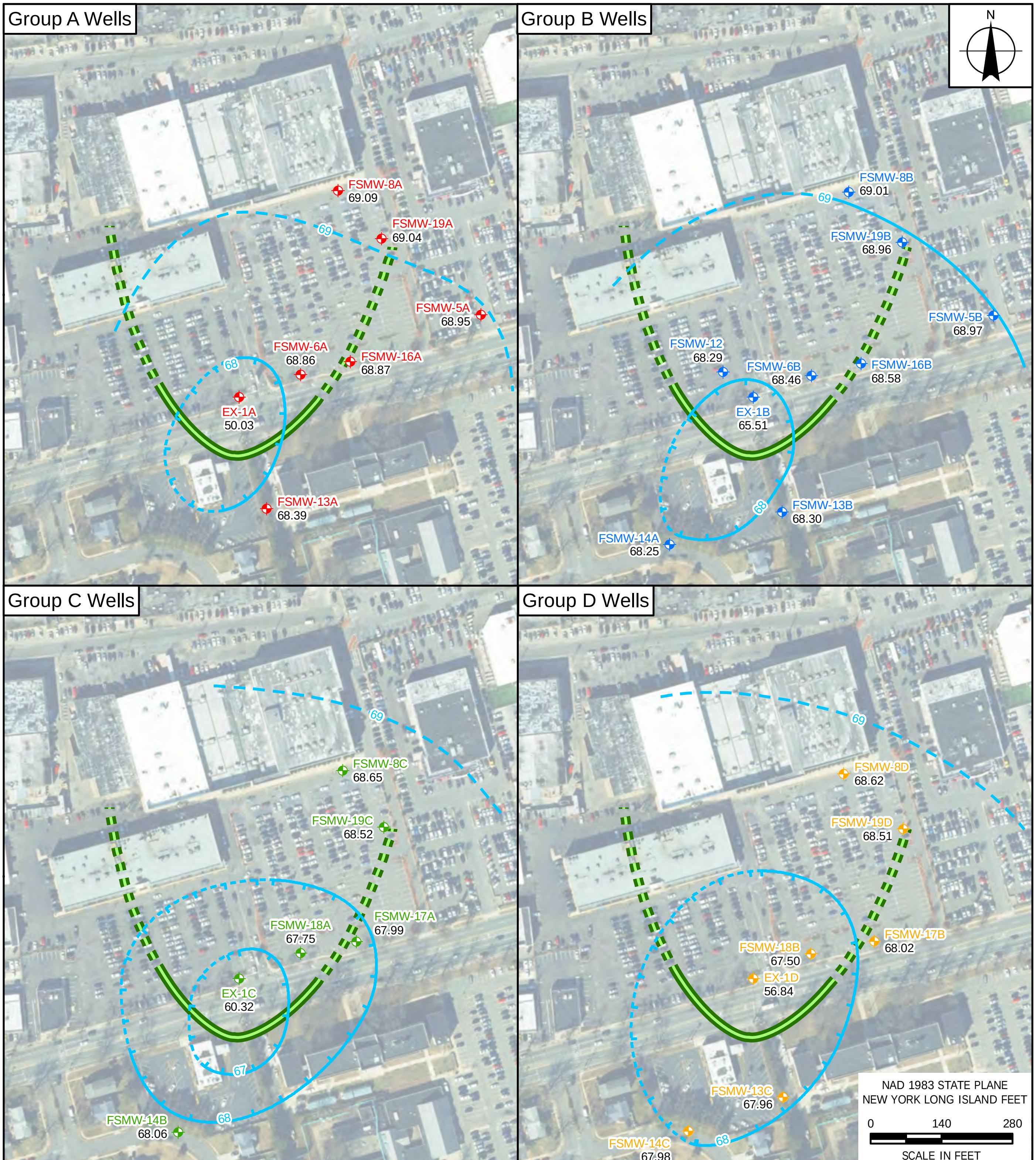

LEGEND

- GROUP A WELLS - SCREENS 50-80 FAMSL
- GROUP B WELLS - SCREENS 119-149 FAMSL
- GROUP C WELLS - SCREENS 159-184 FAMSL
- GROUP D WELLS - SCREENS 221-249 FAMSL
- SHALLOW CAPTURE ZONE (50 TO 150 FEET BGS) (30 GPM) (DASHED WHERE INFERRED)
- DEEP CAPTURE ZONE (150 TO 250 FEET BGS) (48 GPM) (DASHED WHERE INFERRED)
- POTENTIOMETRIC SURFACE DEPRESSION CONTOUR, DASHED WHERE INFERRED
- POTENTIOMETRIC SURFACE CONTOUR, DASHED WHERE INFERRED

NOTES:
FAMSL - FEET ABOVE MEAN SEA LEVEL
GPM - GALLONS PER MINUTE
BGS - BELOW GROUND SURFACE
POTENTIOMETRIC CONTOURS IN FAMSL

FIGURE 13
PUMPING GROUNDWATER POTENTIOMETRIC SURFACE, TEST 5
2280 MINUTES AFTER PUMPING BEGAN
4/6/18 0:00
FROST STREET SITES
WESTBURY, NEW YORK

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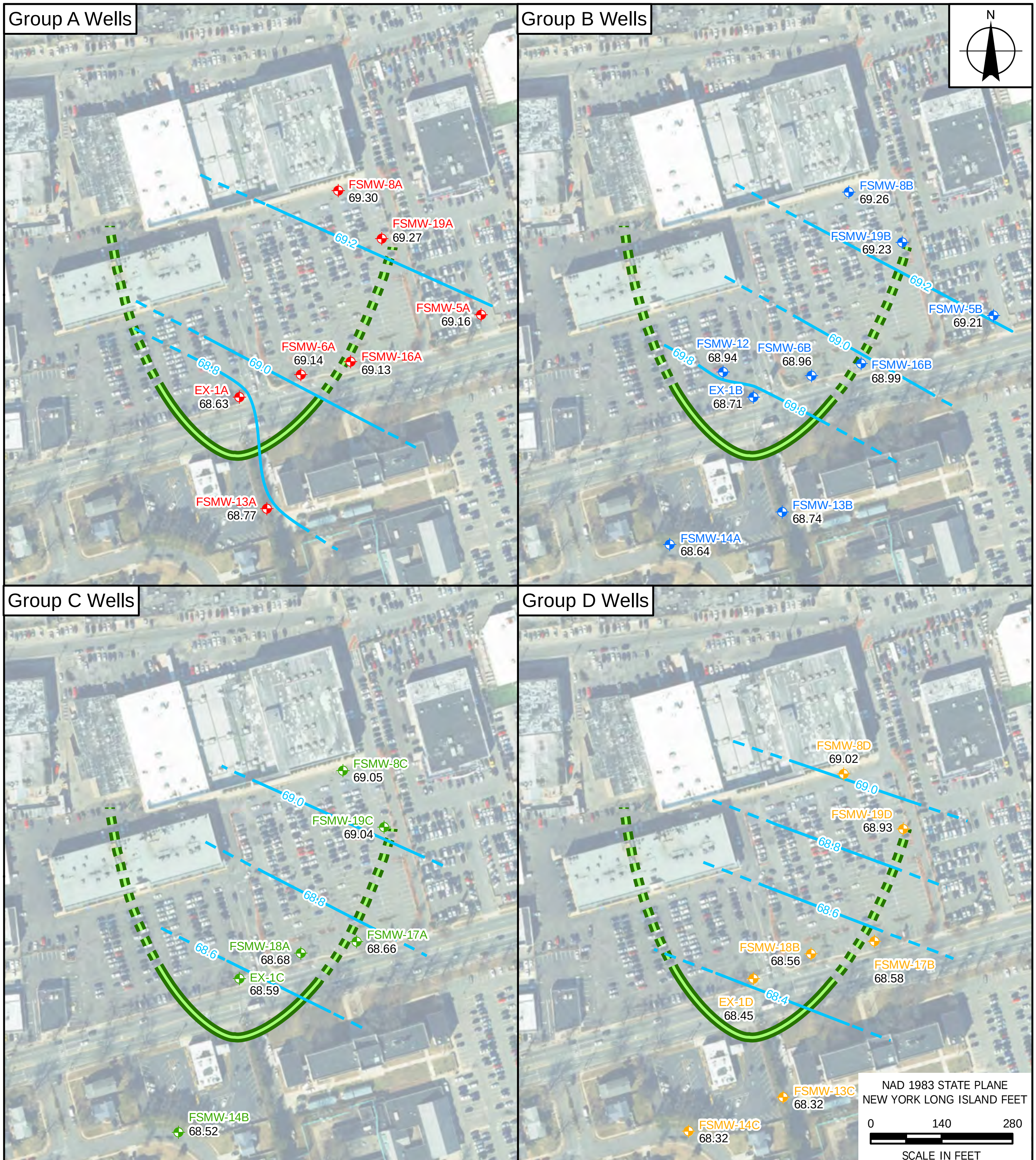

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LEGEND

- GROUP A WELLS - SCREENS 50-80 FAMSL
- GROUP B WELLS - SCREENS 119-149 FAMSL
- GROUP C WELLS - SCREENS 159-184 FAMSL
- GROUP D WELLS - SCREENS 221-249 FAMSL
- SHALLOW CAPTURE ZONE (50 TO 150 FEET BGS) (30 GPM) (DASHED WHERE INFERRED)
- DEEP CAPTURE ZONE (150 TO 250 FEET BGS) (48 GPM) (DASHED WHERE INFERRED)
- POTENTIOMETRIC SURFACE CONTOUR, DASHED WHERE INFERRED

NOTES:
FAMSL - FEET ABOVE MEAN SEA LEVEL
GPM - GALLONS PER MINUTE
BGS - BELOW GROUND SURFACE
POTENTIOMETRIC CONTOURS IN FAMSL

FIGURE 14
STATIC GROUNDWATER POTENTIOMETRIC SURFACE, TEST 5
0 MINUTES AFTER PUMPING BEGAN
4/4/18 9:58
FROST STREET SITES
WESTBURY, NEW YORK

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PROJECT:	0888820265

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Figure 15. Phase 2 Group A Observation Well Hydrographs

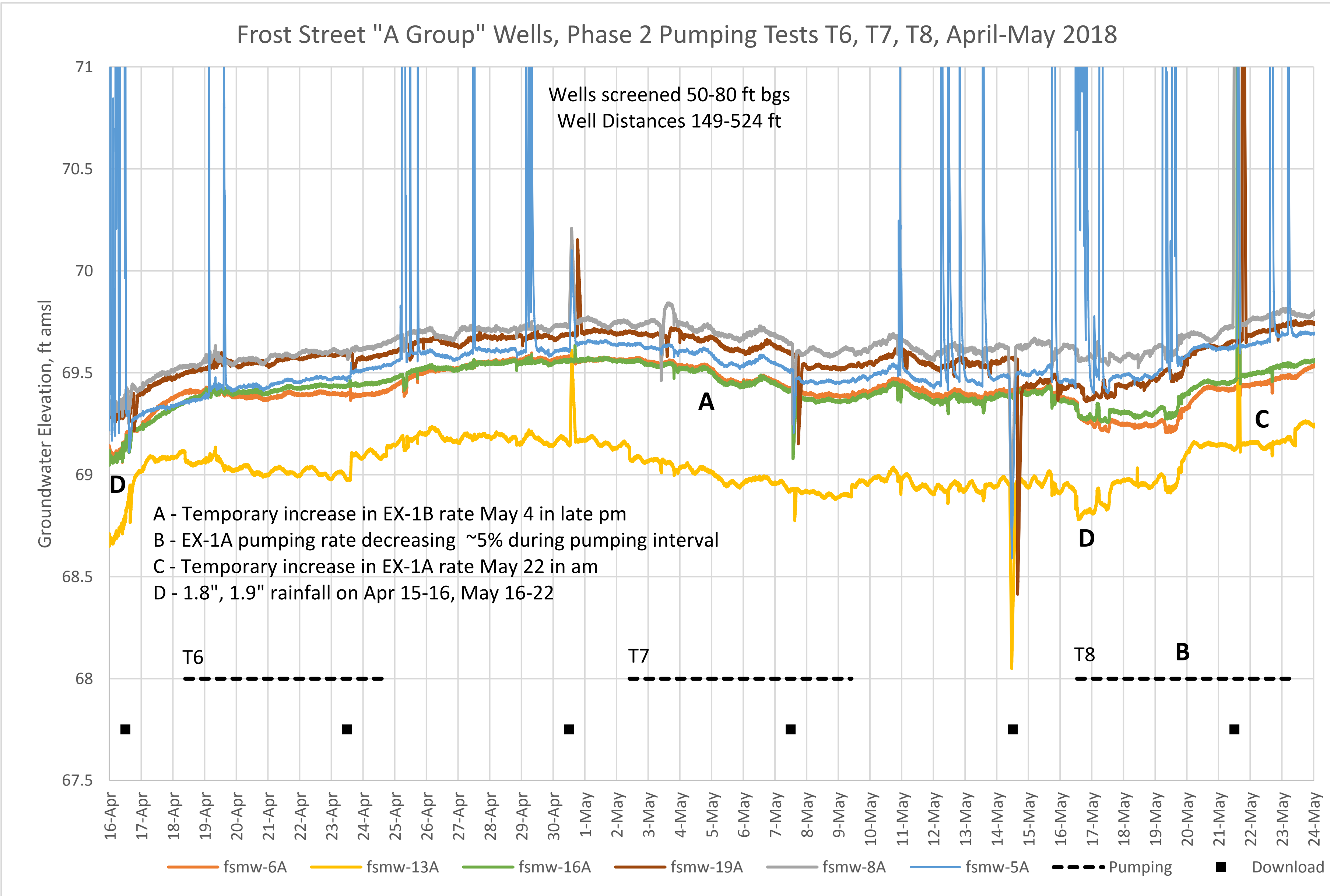


Figure 16. Phase 2 Group B Observation Well Hydrographs

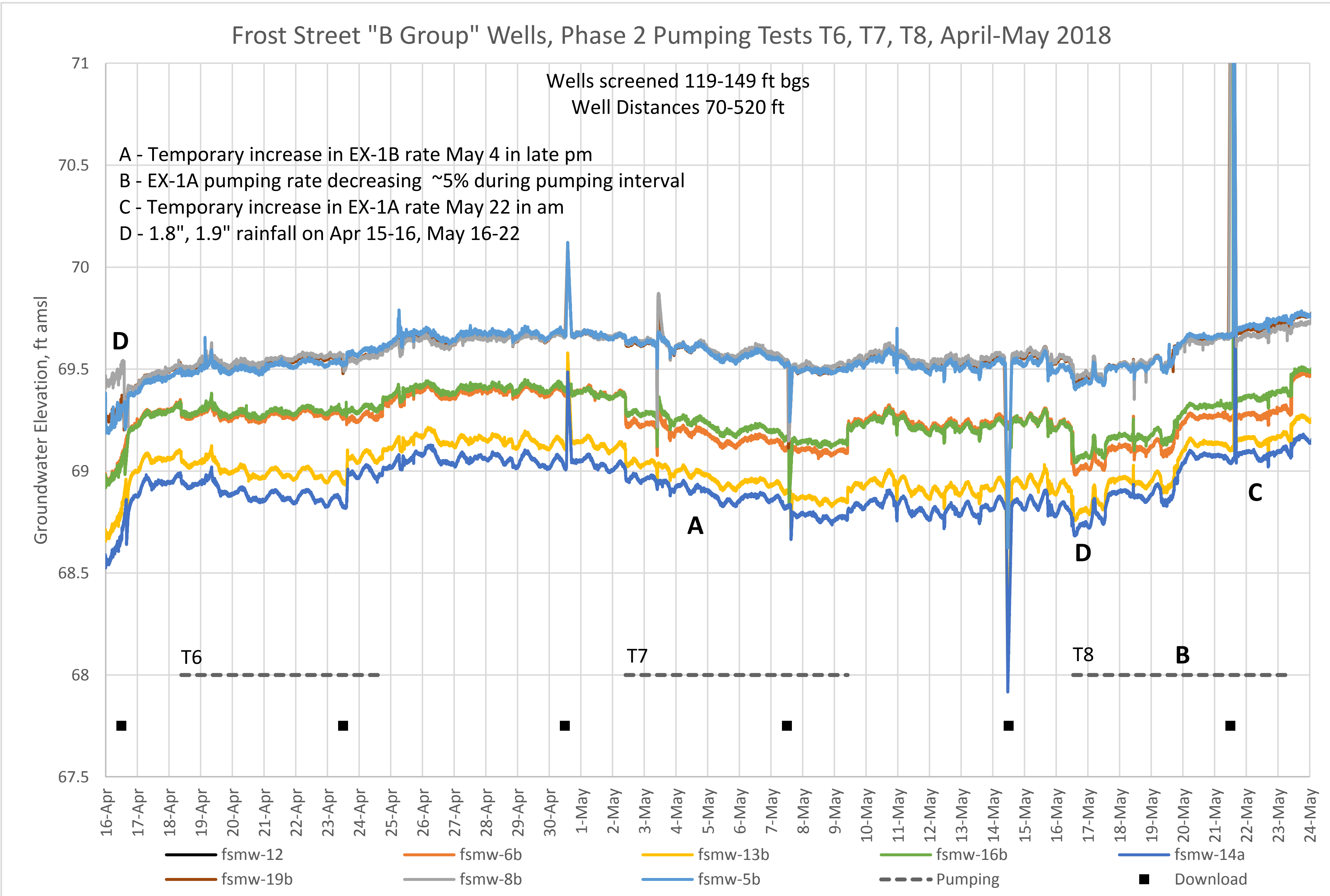


Figure 17. Phase 2 Group C Observation Well Hydrographs

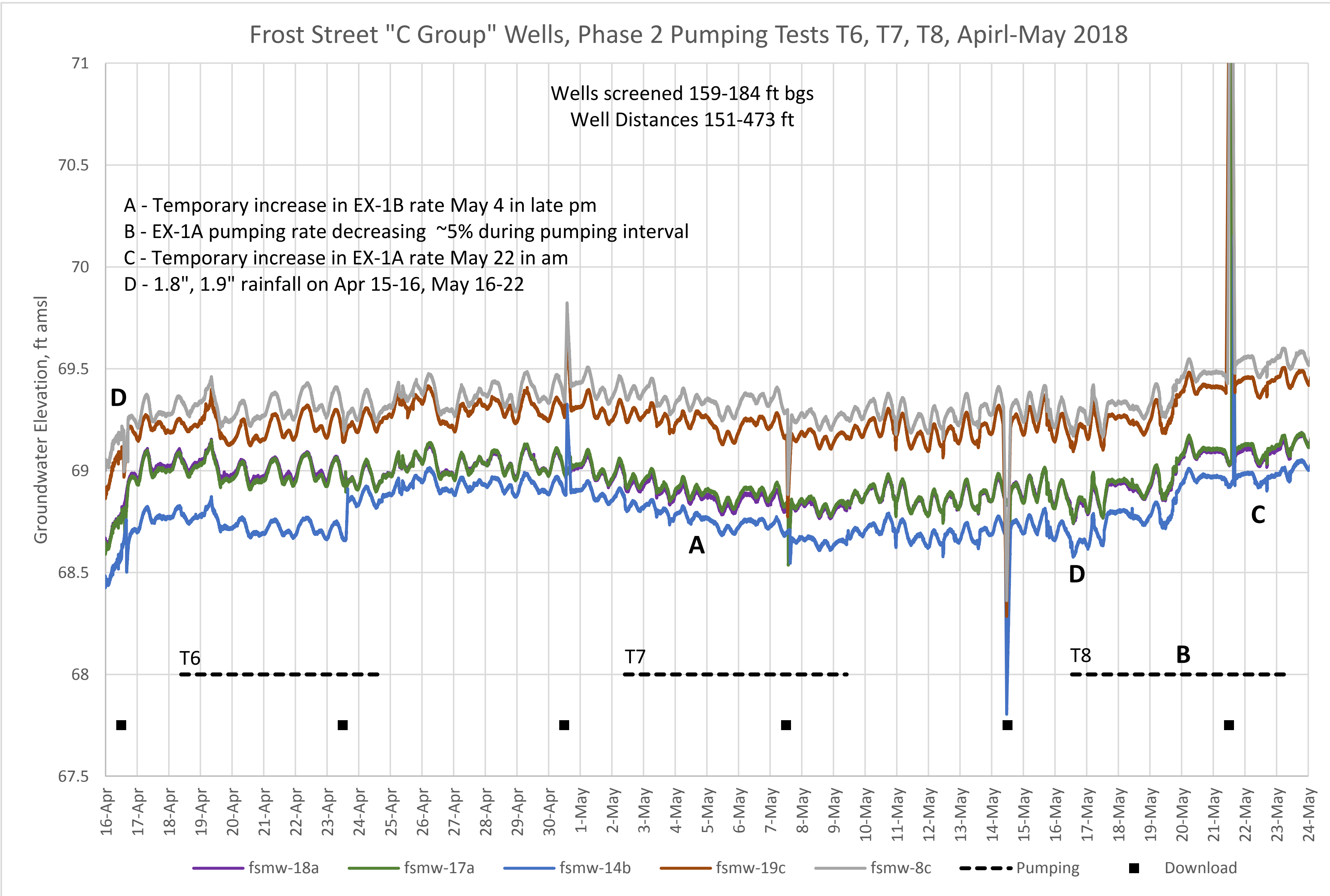
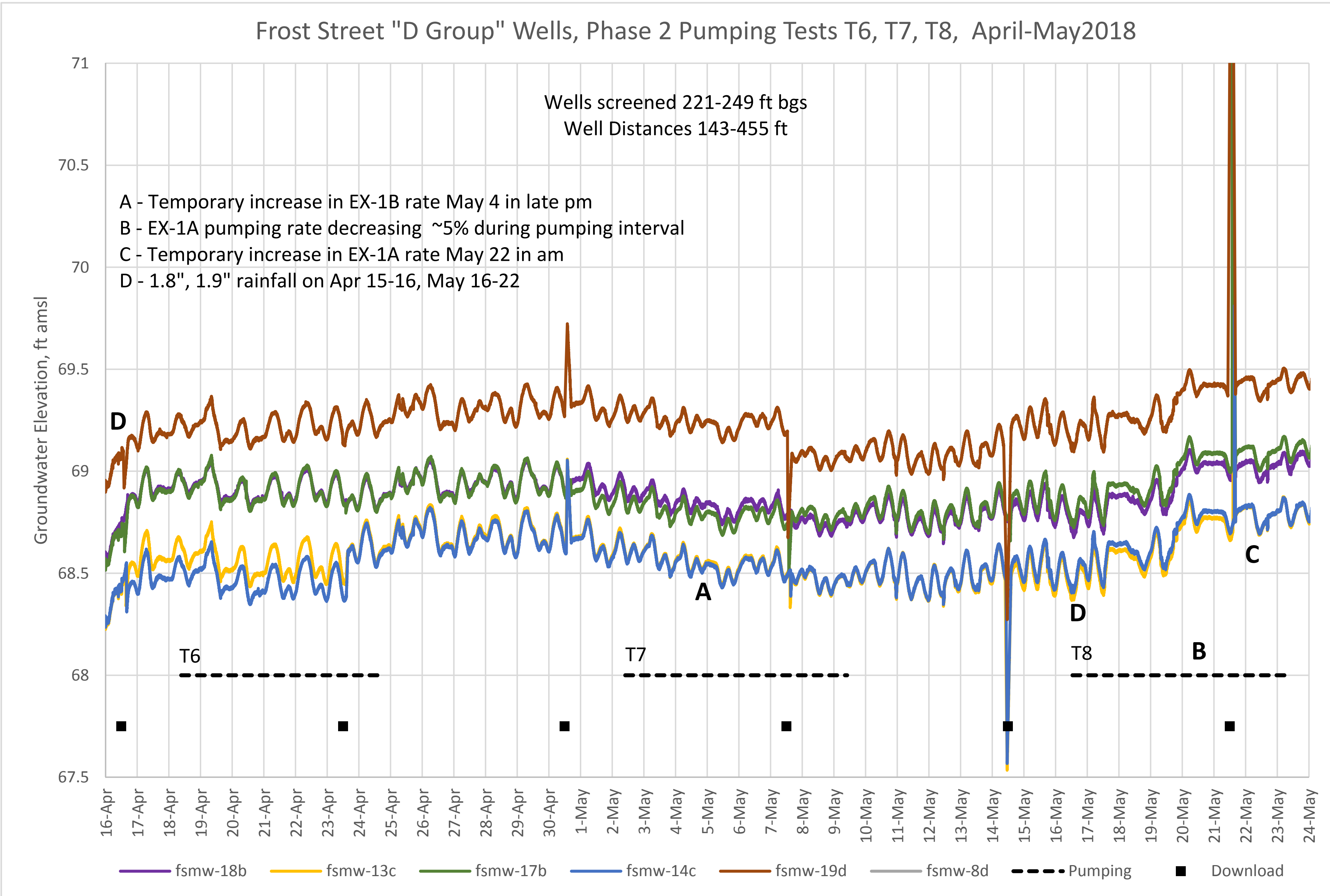


Figure 18. Phase 2 Group D Observation Well Hydrographs



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LEGEND

- GROUP A WELLS - SCREENS 50-80 FAMSL
- GROUP B WELLS - SCREENS 119-149 FAMSL
- GROUP C WELLS - SCREENS 159-184 FAMSL
- GROUP D WELLS - SCREENS 221-249 FAMSL
- SHALLOW CAPTURE ZONE (50 TO 150 FEET BGS) (30 GPM) (DASHED WHERE INFERRED)
- DEEP CAPTURE ZONE (150 TO 250 FEET BGS) (48 GPM) (DASHED WHERE INFERRED)

NOTES:
FAMSL - FEET ABOVE MEAN SEA LEVEL
GPM - GALLONS PER MINUTE
BGS - BELOW GROUND SURFACE

FIGURE 19
WATER LEVEL DRAWDOWN, TEST 6
7401 MINUTES AFTER PUMPING BEGAN
4/23/18 12:30
FROST STREET SITES
WESTBURY, NEW YORK

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LEGEND

- GROUP A WELLS - SCREENS 50-80 FAMSL
- GROUP B WELLS - SCREENS 119-149 FAMSL
- GROUP C WELLS - SCREENS 159-184 FAMSL
- GROUP D WELLS - SCREENS 221-249 FAMSL
- SHALLOW CAPTURE ZONE (50 TO 150 FEET BGS) (30 GPM) (DASHED WHERE INFERRED)
- DEEP CAPTURE ZONE (150 TO 250 FEET BGS) (48 GPM) (DASHED WHERE INFERRED)

NOTES:
FAMSL - FEET ABOVE MEAN SEA LEVEL
GPM - GALLONS PER MINUTE
BGS - BELOW GROUND SURFACE

FIGURE 20
WATER LEVEL DRAWDOWN, TEST 7
10088 MINUTES AFTER PUMPING BEGAN
5/9/18 9:56
FROST STREET SITES
WESTBURY, NEW YORK

REQUESTED BY:	AJ
DRAWN BY:	NR
DATE:	7/16/2018
PROJECT:	0888820265

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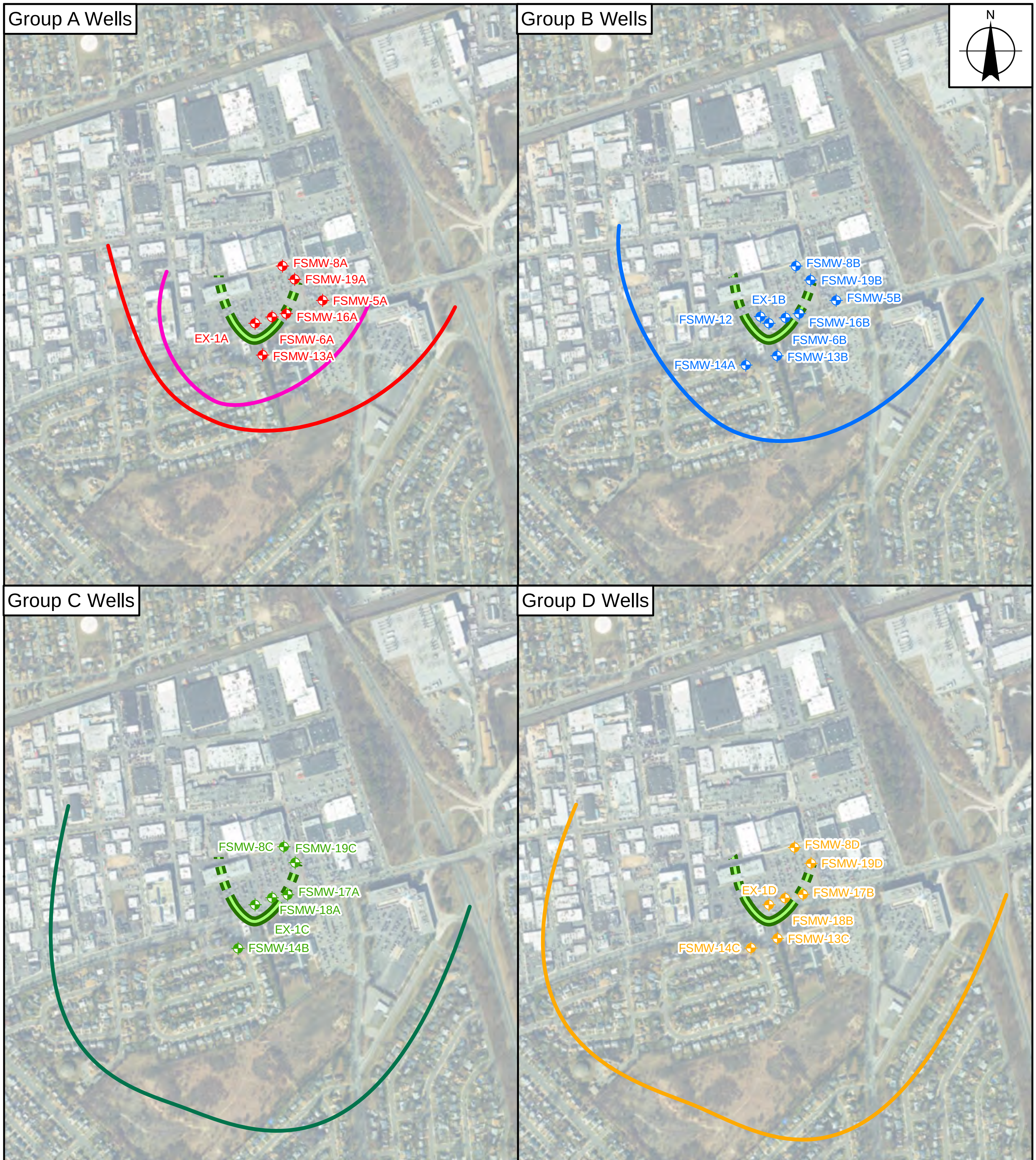
DATA SOURCES: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



LEGEND

- GROUP A WELLS - SCREENS 50-80 FAMSL
- GROUP B WELLS - SCREENS 119-149 FAMSL
- GROUP C WELLS - SCREENS 159-184 FAMSL
- GROUP D WELLS - SCREENS 221-249 FAMSL
- DESIGN SHALLOW CAPTURE ZONE (50 TO 150 FEET BGS) (30 GPM) (DASHED WHERE INFERRED)
- DESIGN DEEP CAPTURE ZONE (150 TO 250 FEET BGS) (48 GPM) (DASHED WHERE INFERRED)
- MODEL SIMULATED DESIGN CAPTURE ZONE EX-1A1
- MODEL SIMULATED DESIGN CAPTURE ZONE EX-1A2
- MODEL SIMULATED DESIGN CAPTURE ZONE EX-1B
- MODEL SIMULATED DESIGN CAPTURE ZONE EX-1C
- MODEL SIMULATED DESIGN CAPTURE ZONE EX-1D

NOTES:
FAMSL - FEET ABOVE MEAN SEA LEVEL
GPM - GALLONS PER MINUTE
BGS - BELOW GROUND SURFACE

NAD 1983 STATE PLANE
NEW YORK LONG ISLAND FEET

0 500 1,000
SCALE IN FEET

FIGURE 21
MODEL SIMULATED DESIGN PUMPING RATE CAPTURE ZONES
FROST STREET SITES
WESTBURY, NEW YORK

REQUESTED BY:	AJ
DRAWN BY:	NR
DATE:	7/30/2018
PROJECT:	0888820265

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X:\FrostStreet\ModelSimulatedDesignPumpingRateCaptureZone.mxd

DATA SOURCES: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

LEGEND

- GROUP A WELLS - SCREENS 50-80 FAMSL
- GROUP B WELLS - SCREENS 119-149 FAMSL
- GROUP C WELLS - SCREENS 159-184 FAMSL
- GROUP D WELLS - SCREENS 221-249 FAMSL
- DESIGN SHALLOW CAPTURE ZONE (50 TO 150 FEET BGS) (30 GPM) (DASHED WHERE INFERRED)
- DESIGN DEEP CAPTURE ZONE (150 TO 250 FEET BGS) (48 GPM) (DASHED WHERE INFERRED)
- MODEL SIMULATED ALTERNATE CAPTURE ZONE EX-1A1
- MODEL SIMULATED ALTERNATE CAPTURE ZONE EX-1A2
- MODEL SIMULATED ALTERNATE CAPTURE ZONE EX-1B
- MODEL SIMULATED ALTERNATE CAPTURE ZONE EX-1C
- MODEL SIMULATED ALTERNATE CAPTURE ZONE EX-1D

NOTES:
FAMSL - FEET ABOVE MEAN SEA LEVEL
GPM - GALLONS PER MINUTE
BGS - BELOW GROUND SURFACE

NAD 1983 STATE PLANE
NEW YORK LONG ISLAND FEET

0 500 1,000
SCALE IN FEET

FIGURE 22
MODEL SIMULATED ALTERNATE PUMPING RATE CAPTURE ZONES
FROST STREET SITES
WESTBURY, NEW YORK

REQUESTED BY:	AJ
DRAWN BY:	NR
DATE:	7/30/2018
PROJECT:	0888820265

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DATA SOURCES: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Tables

Table 1. Pumping Test Schedule
March - May 2018

Test Phase	Test ID	Pumped Well (s)	Start	End	Duration (minutes)	Rate (gpm)
Phase 1	T1	EX-1A	3/29/2018 8:30	3/29/2018 16:30	480	29.8
	T2	EX-1B	3/30/2018 8:30	3/30/2018 16:30	480	30
	T3	EX-1C	4/2/2018 6:11	4/2/2018 14:11	480	4705
	T4	EX-1D	4/3/2018 5:40	4/3/2018 13:30	470	48.1
	T5	EX-1A,B,C,D	4/4/2018 10:00	4/11/2018 10:00	10,080	28.9/30.0/45.8/44.7
Phase 2	T6	EX-1A	4/18/2018 9:18	4/24/2018 17:39	9,141	29
	T7	EX-1B	5/2/2018 9:50	5/9/2018 10:00	10,090	30.8
	T8	EX-1A,B	5/16/2018 12:49	5/23/2018 10:19	9,930	29.0/29.9

Table 2. Pumping Test Observation Well Groups

Well Group	Well	X	Y	Grnd Elev	Scrn Top ft bgs	Scrn Bott ft bgs	Sceen Length	Scrn Top ft amsl	Scrn Bott ft amsl	Distance from EX-1
A	EX-1A	1107359	214880.1	120.53	50	100	50	70.53	20.53	0
	MW-6A	1107499	214930.4	119.46	59	69	10	60.46	50.46	149
	MW-13A	1107432	214665.6	118.41	69	79	10	49.41	39.41	227
	MW-16A	1107597	214955.6	119.13	50	60	10	69.13	59.13	250
	MW-19A	1107663	215185.1	120.83	70	80	10	50.83	40.83	431
	MW-8A	1107572	215292.9	121.89	64	74	10	57.89	47.89	465
	MW-5A	1107855	215048.6	118.35	60	70	10	58.35	48.35	524
B	EX-1B	1107363	214904.4	120.55	100	150	50	20.55	-29.45	25
	MW-12	1107317	214935.8	121.44	139	149	10	-17.56	-27.56	70
	MW-6B	1107492	214928.3	119.49	137	147	10	-17.51	-27.51	142
	MW-13B	1107434	214659.3	118.2	119	129	10	-0.8	-10.8	233
	MW-16B	1107590	214952.8	119.28	127	137	10	-7.72	-17.72	242
	MW-14A	1107249	214584.3	117.49	119	129	10	-1.51	-11.51	315
	MW-19B	1107671	215191.1	120.82	120	130	10	0.82	-9.18	441
	MW-8B	1107566	215290.9	122.04	132	142	10	-9.96	-19.96	460
	MW-5B	1107851	215047	118.3	130	140	10	-11.7	-21.7	520
C	EX-1C	1107362	214898.4	120.5	150	200	50	-29.5	-79.5	19
	MW-18A	1107499	214936.4	119.32	172	182	10	-52.68	-62.68	151
	MW-17A	1107609	214959.2	119.04	174	184	10	-54.96	-64.96	262
	MW-14B	1107263	214580.3	117.55	159	169	10	-41.45	-51.45	315
	MW-19C	1107673	215181.5	120.71	170	180	10	-49.29	-59.29	435
	MW-8C	1107582	215297.5	121.82	170	180	10	-48.18	-58.18	473
D	EX-1D	1107360	214887.7	120.55	200	240	40	-79.45	-119.45	8
	MW-18B	1107491	214934.7	119.43	221	231	10	-101.57	-111.57	143
	MW-13C	1107436	214651.9	118.22	239	249	10	-120.78	-130.78	241
	MW-17B	1107616	214960.4	118.91	223	233	10	-104.09	-114.09	269
	MW-14C	1107257	214582.5	117.36	239	249	10	-121.64	-131.64	315
	MW-19D	1107659	215198.7	121	223	233	10	-102	-112	438
	MW-8D	1107556	215290.6	122.23	223	233	10	-100.77	-110.77	455

Table 3. Summary of Drawdown and Water Levels for Phase 1 and 2 Pumping Tests
March - May 2018

Test ID		T1[a]	T2[b]	T3	T4	T5				T6	T7	T8	Distance to EX-1A, approximate
Well(s) Pumped		EX-1A	EX-1B	EX-1C	EX-1D	EX-1A,B, C,D				EX-1A	EX-1B	EX-1A,B	
Q_{total}, gpm		29.8	30	47.5	48.1	154.8 initial, 147.8 after 4/6 @ 16:00				29	30.8	58.9	
Start		3/29/18 8:29	3/30/18 8:29	4/2/18 6:10	4/3/18 5:35	4/4/18 9:58	4/4/18 9:58	4/4/18 9:58	--	4/18/18 9:09	5/2/18 9:48	5/16/18 12:29	
End		3/29/18 16:29	3/30/18 16:29	4/2/18 14:10	4/3/18 13:25	4/6/18 0:00	4/11/18 7:30	--	4/6/18 0:00	4/23/18 12:30	5/9/18 9:56	5/23/18 10:16	
WL or Ddn?		Ddn @ 480 min	Ddn @ 480 min	Ddn @ 480 min	Ddn @ 480 min	Ddn @ 2280 min	Ddn @ 9932 min	***SWL @ 0 min***	***PWL @ 2280 min***	Ddn @ 7401 min	Ddn @ 10088 min	Ddn @ 9936 min	
Group A Wells (screen 50-80 ft bgs)	EX-1A	19.5	0.12	0.04	0.00	18.6	17.3	***68.63***	***50.03***	18.9	0.69	10.0	0
	6A	0.02	0.01	0.00	-0.02	0.28	0.40	***69.14***	***68.86***	0.01	0.18	-0.15	149
	13A	0.09	0.13	0.08	0.04	0.39	0.37	***68.77***	***68.39***	0.14	0.24	-0.26	227
	16A	0.00	0.03	0.01	-0.03	0.27	0.26	***69.13***	***68.87***	-0.09	0.19	-0.21	250
	19A	0.00	0.04	0.00	-0.04	0.23	[c]	***69.27***	***69.04***	-0.02	0.16	-0.33	431
	8A	-0.01	0.03	-0.01	-0.04	0.21	0.10	***69.30***	***69.09***	-0.04	0.13	-0.19	465
	5A	0.00	0.04	-0.03	-0.11	0.22	0.13	***69.16***	***68.95***	-0.12	0.18	-0.26	524
Group B Wells (screen 119-149 ft bgs)	EX-1B	0.15	2.7	0.21	0.05	3.2	3.0	***68.71***	***65.51***	0.10	3.0	2.1	25
	12	0.11	0.30	0.10	0.05	0.65	0.57	***68.94***	***68.29***	0.08	0.45	0.01	70
	6B	0.10	0.20	0.09	0.05	0.50	0.43	***68.96***	***68.46***	0.07	0.27	-0.11	142
	13B	0.10	0.15	0.11	0.08	0.44	0.42	***68.74***	***68.30***	0.14	0.25	-0.28	233
	16B	0.08	0.14	0.06	0.02	0.40	0.35	***68.99***	***68.58***	0.04	0.22	-0.21	242
	14A	0.07	0.14	0.11	0.08	0.39	0.37	***68.64***	***68.25***	0.15	0.25	-0.32	315
	19B	0.03	0.09	0.02	-0.02	0.26	[c]	***69.23***	***68.96***	0.02	0.16	-0.21	441
	8B	0.03	0.08	0.02	-0.03	0.25	[c]	***69.26***	***69.01***	0.02	0.14	-0.17	460
	5B	0.02	0.08	0.03	-0.02	0.24	[c]	***69.21***	***68.97***	-0.04	0.16	-0.27	520
Group C Wells (screen 159-184 ft bgs)	EX-1C	0.11	0.21	7.2	0.97	8.3	7.8	***68.59***	***60.32***	0.12	0.52	-0.23	19
	18A	[a]	*0.07*	0.43	0.36	0.93	0.75	***68.68***	***67.75***	0.13	0.16	-0.27	151
	17A	[a]	*0.08*	0.29	0.26	0.66	0.48	***68.66***	***67.99***	0.14	0.16	-0.29	262
	14B	[a]	*0.03*	0.16	0.13	0.45	0.43	***68.52***	***68.06***	0.15	0.22	-0.32	315
	19C	[a]	*0.03*	0.15	0.10	0.52	[c]	***69.04***	***68.52***	0.10	0.11	-0.30	435
	8C	[a]	*0.04*	0.16	0.15	0.40	0.21	***69.05***	***68.65***	0.15	0.13	-0.32	473
Group D Wells (screen 221-249 ft bgs)	EX-1D	0.12	0.18	0.97	10.3	11.6	10.7	***68.45***	***56.84***	0.13	0.60	-0.29	8
	18B	[a]	*0.00*	0.44	0.54	1.06	0.82	***68.56***	***67.50***	0.13	0.18	-0.29	143
	13C	[a]	*0.04*	0.17	0.18	0.37	0.23	***68.32***	***67.96***	0.20	0.16	-0.36	241
	17B	[a]	*0.02*	0.24	0.26	0.56	0.42	***68.58***	***68.02***	0.14	0.08	-0.31	269
	14C	[a]	*0.03*	0.16	0.16	0.34	0.17	***68.32***	***67.98***	0.19	0.15	-0.33	315
	19D	[a]	*-0.01*	0.17	0.17	0.41	0.21	***68.93***	***68.51***	0.13	0.22	-0.28	438
	8D	[a]	*-0.03*	0.17	0.16	0.41	0.22	***69.02***	***68.62***	0.14	0.11	-0.30	455

Notes: Qtotal, gpm - Total pumping rate of one or more wells in gallons per minute
WL - static water levels for start of pumping interval (SWL) or during pumping (PWL)
Ddn - drawdown at designated time in minutes after pumping interval began
Wells grouped according to screen depth interval, below ground surface, in aquifer
Shaded cells - drawdown in well(s) being pumping during test
[a] Drawdown for C and D observation wells expected to be negligible for 8-hr pumping, and was obscured by background water level changes
[b] Drawdown for C and D observation wells reduced by 0.12 and 0.20 ft, respectively, to account for background water level changes during s8-hr pumping - shown in italic font
[c] Spurious data not used

Table 4. Capture Zone Dimensions

Pumping Scenario	Extraction Well	Model Layer	Scenario CZ Downgradient feet	Scenario CZ Width feet	Design CZ Downgradient feet	Design CZ Width feet
Design Pumping	EX-1A	1	609	1,327	116	525
		3	751	2,152		
	EX-1B	4	798	2,217		
	EX-1C	6	1,511	2,874		
	EX-1D	7	1,513	3,049		
Alternate Pumping	EX-1A	1	165	532	116	525
		3	199	577		
	EX-1B	4	186	607		
	EX-1C	6	226	674		
	EX-1D	7	233	678		

Notes:

Downgradient capture zone (CZ) measured from well EX-1 along flowline downgradient to groundwater divide stagnation point during pumping.

CZ width measured perdendicular to groundwater flow line through well EX-1.

Appendix A
Boring Log and Gamma Log – EX-1D

ENSAFE

	Location ID:	EX-1D
	Sketch of Boring Location	
Client: Frost Street Parties	Start Date:	7/24/2017
Project #: 0888820265	End Date:	7/28/2017
Purpose: Profile Boring	Sampling Method:	Rotosonic
Project: Frost Street Sites	Drilling Equipment:	Rotosonic Drill Rig
Location: Westbury, New York	Drilling Company:	Summit Drilling
	Geologist:	V. Varricchio

Sample Number	Sample Interval (FT)	Recovery (IN)	PID Reading (ppm)	USCS	Depth (FT)	Lithologic Description Visual-Manual Description (ASTM D 2488-06)	Analytical Sample
1	0-5	NA	NA	NA	0	Air knife.	
					1		
					2		
					3		
					4		
2	5-15	78	0.0	SW-GW	5	0-16": WELL GRADED SAND AND GRAVEL, fine to coarse, with silt and cobbles, loose, subangular, dark brown.	
			0.0		6		
			0.0	SP	7	16-29": POORLY GRADED SAND, fine sand, trace coarse gravel, brown.	
			0.0		8		
			0.0		9	29-39": POORLY GRADED SAND, trace coarse gravel, loose, dark brown.	
			0.0		10	39-52": POORLY GRADED SAND, fine sand, trace coarse gravel, brown.	
			0.0		11		
			0.0		12	52-78": POORLY GRADED SAND, fine sand, trace coarse gravel, light brown.	
			0.0		13		
			0.0		14		
3	15-25	83	0.0	GW	15	0-12": WELL GRADED GRAVEL, fine to coarse subrounded gravel, some fine to coarse subrounded sand, tan, moist.	
			0.0	SW-GW	16	12-59": WELL GRADED SAND AND GRAVEL, fine to coarse subrounded sand, fine to coarse subrounded gravel, brown.	
			0.0		17		
			0.0		18		
			0.0		19		
			0.0		20		
			0.0		21		
			0.0	SP	22	59-83": POORLY GRADED SAND, fine sand, few fine subrounded gravel, brown.	
			0.0		23		
			0.0		24		
4	25-35	94	0.0	SW	25	0-30": WELL GRADED SAND, fine to coarse subrounded sand, trace fine subrounded gravel, light brown.	
			0.0		26		
			0.0		27		
			0.0		28	30-53": WELL GRADED SAND, medium to coarse subangular sand, some fine subrounded gravel, brown.	
			0.0		29		
			0.0		30		
			0.0	SP	31	53-69": POORLY GRADED SAND, subrounded, brown.	
			0.0	SW	32	69-94": WELL GRADED SAND, fine to coarse subangular sand, few fine to coarse subrounded gravel, trace silt reddish brown.	
			0.0		33		
			0.0		34		

ENSAFE	Frost Street Sites Westbury, New York	Location ID: EX-1D Page 2 of 7

Sample Number	Sample Interval (FT)	Recovery (IN)	PID Reading (ppm)	USCS	Depth (FT)	Lithologic Description Visual-Manual Description (ASTM D 2488-06)	Analytical Sample
5	35-45	82	0.0	SW	35	0-27": WELL GRADED SAND, fine to medium subangular sand, few fine to coarse subrounded gravel, trace rounded cobble, light brown.	
			0.0		36		
			0.0		37		
			0.0	SM	38	27-55": SILTY SAND, poorly graded fine sand, trace fine subrounded gravel.	
			0.0		39		
			0.0		40		
			0.0		41		
			0.0	SW-GW	42	55-82": WELL GRADED SAND AND GRAVEL, fine to coarse subrounded sand, subrounded gravel, trace subrounded cobbles, reddish brown, dry.	
			0.0		43		
			0.0		44		
6	45-55	100	0.0	SP	45	0-82": POORLY GRADED SAND, fine sand, light brown, moist.	
			0.0		46		
			0.0		47		
			0.0		48		
			0.0		49		
			0.0		50		
			0.0		51		
			0.0		52		
			0.0	ML	53	82-100": SANDY SILT, light brown.	
			0.0		54		
7	55-65	96	0.0	SP	55	0-96": POORLY GRADED SAND, fine sand, trace silt, light brown.	FS-EX-1D(55-57)072517
			0.0		56		
			0.0		57		
			0.0		58		
			0.0		59		
			0.0		60		
			0.0		61		
			0.0		62		
			0.0		63		
			0.0		64		
8	65-75	115	0.0	SP	65	0-24": POORLY GRADED SAND, medium sand, yellowish brown.	FS-EX-1D(65-67)072517
			0.0		66		
			0.0	CL	67	24-54": CLAY, trace fine sand, gray.	
			0.0		68		
			0.0		69		
			0.0	SM	70	54-94": SILTY SAND, light brown with gray clay lens 60-68".	
			0.0	CH SM	71		
			0.0		72		
			0.0	CL	73	94-102": CLAY, trace fine sand.	
			0.0	SP	74	102-115": POORLY GRADED SAND, fine sand, trace silt, yellow brown	

ENSAFE	Frost Street Sites Westbury, New York	Location ID: EX-1D Page 3 of 7

Sample Number	Sample Interval (FT)	Recovery (IN)	PID Reading (ppm)	USCS	Depth (FT)	Lithologic Description Visual-Manual Description (ASTM D 2488-06)	Analytical Sample
9	75-85	60	0.0	SP	75	0-60": POORLY GRADED SAND, fine sand, light brown (0-30") to medium brown (30-42") to reddish brown (42-60").	FS-EX-1D(75-77)072517
			0.0		76		
			0.0		77		
			0.0		78		
			0.0		79		
			0.0		80		
			0.0		81		
			0.0		82		
			0.0		83		
			0.0		84		
10	85-95	128	0.0	SP	85	0-128": POORLY GRADED SAND, fine sand, medium brown (0-122") to reddish brown (122-128").	FS-EX-1D(85-87)072517
			0.0		86		
			0.0		87		
			0.0		88		
			0.0		89		
			0.0		90		
			0.0		91		
			0.0		92		
			0.0		93		
			0.0		94		
11	95-105	116	0.0	SP	95	0-18": POORLY GRADED SAND, fine sand, light brown.	FS-EX-1D(95-97)072617
			0.0	SM	96	18-54": SILTY SAND, fine sand, brown.	
			0.0		97		
			0.0		98		
			0.0		99		
			0.0	SP	100	54-116": POORLY GRADED SAND, fine sand, grayish brown.	
			0.0		101		
			0.0		102		
			0.0		103		
			0.0		104		
12	105-115	65	0.0	SP	105	0-65": POORLY GRADED SAND, fine sand, light brown.	FW-EX-1D(105-107)072617 FS-DUP-072617/MS/MSD
			0.0		106		
			0.0		107		
			0.0		108		
			0.0		109		
			0.0		110		
			0.0		111		
			0.0		112		
			0.0		113		
			0.0		114		

ENSAFE	Frost Street Sites Westbury, New York	Location ID: **EX-1D**

Sample Number	Sample Interval (FT)	Recovery (IN)	PID Reading (ppm)	USCS	Depth (FT)	Lithologic Description Visual-Manual Description (ASTM D 2488-06)	Analytical Sample
13	115-125	106	0.0	SP	115	0-48": POORLY GRADED SAND, fine sand, reddish brown (0-30") to light brown (30-48").	FS-EX-1D(115-117)072617
			0.0		116		
			0.0		117		
			0.0		118		
			5.5	SP-SM	119	48-54": POORLY GRADED SAND WITH SILT, fine sand light brown.	FS-SOIL-EX-1D(119-120)072617 FS-SOIL-DUP
			0.0	SP	120	54-96": POORLY GRADED SAND, fine sand, light brown.	
			0.0		121		
			0.0		122		
			0.0		123		
			0.0	SM	124	96-106": SILTY SAND, fine sand, trace clay, reddish brown.	
14	125-135	89	0.0	SP	125	0-89": POORLY GRADED SAND, fine sand, light brown.	FS-EX-1D(125-127)072617
			0.0		126		
			0.0		127		
			0.0		128		
			0.0		129		
			0.0		130		
			0.0		131		
			0.0		132		
			0.0		133		
			0.0		134		
15	135-145	97	0.0	SP	135	0-97": POORLY GRADED SAND, fine sand, reddish brown (0-48") to light brown (48-97").	FS-EX-1D(135-137)072617
			0.0		136		
			0.0		137		
			0.0		138		
			0.0		139		
			0.0		140		
			0.0		141		
			0.0		142		
			0.0		143		
			0.0		144		
16	145-155	112	0.0	SP	145	0-66": POORLY GRADED SAND, fine sand, light brown (0-18") to reddish brown (18-66").	FS-EX-1D(145-147)072617
			0.0		146		
			0.0		147		
			0.0		148		
			0.0		149		
			0.0		150		
			0.0	CH	151	66-80": FAT CLAY, trace fine sand, reddish brown and gray mottled.	
			0.0	ML	152	80-112": SANDY SILT, fine sand, grayish brown with dark gray lens 80-92".	
			0.0		153		
			0.0		154		

Frost Street Sites
Westbury, New York

Location ID: **EX-1D**

Sample Number	Sample Interval (FT)	Recovery (IN)	PID Reading (ppm)	USCS	Depth (FT)	Lithologic Description Visual-Manual Description (ASTM D 2488-06)	Analytical Sample
17	155-165	100	0.0	SP	155	0-100": POORLY GRADED SAND, fine sand, reddish brown (0-30") to light brown (30-100").	FS-EX-1D(155-157)072617
			0.0		156		
			0.0		157		
			0.0		158		
			0.0		159		
			0.0		160		
			0.0		161		
			0.0		162		
			0.0		163		
			0.0		164		
18	165-175	114	0.0	SP	165	0-34": POORLY GRADED SAND, fine sand, reddish brown.	FS-EX-1D(165-167)072717
			0.0		166		
			0.0		167		
			0.0	SP-SC	168	34-54": POORLY GRADED SAND WITH CLAY, fine sand, light brown.	
			0.0		169		
			0.0	SP	170	54-114": POORLY GRADED SAND, fine sand, reddish brown (54-96") to light brown (96-114").	
			0.0		171		
			0.0		172		
			0.0		173		
			0.0		174		
19	175-185	114	0.0	SP	175	0-114": POORLY GRADED SAND, fine sand, light brown.	FS-EX-1D(175-177)072717
			0.0		176		
			0.0		177		
			0.0		178		
			0.0		179		
			0.0		180		
			0.0		181		
			0.0		182		
			0.0		183		
			0.0		184		
20	185-195	107	0.0	SP	185	0-107": POORLY GRADED SAND, fine to medium sand, brown.	FS-EX-1D(185-187)072717
			0.0		186		
			0.0		187		
			0.0		188		
			0.0		189		
			0.0		190		
			0.0		191		
			0.0		192		
			0.0		193		
			0.0		194		

ENSAFE	Frost Street Sites Westbury, New York	Location ID: EX-1D Page 6 of 7

Sample Number	Sample Interval (FT)	Recovery (IN)	PID Reading (ppm)	USCS	Depth (FT)	Lithologic Description Visual-Manual Description (ASTM D 2488-06)	Analytical Sample
21	195-205	118	0.0	SP	195	0-72": POORLY GRADED SAND, fine sand, brown.	FS-EX-1D(195-197)072717
			0.0		196		
			0.0		197		
			0.0		198		
			0.0		199		
			0.0		200		
			0.5	SM	201	72-118:" SILTY SAND, fine sand, light brown with lens of dark gray silt 78-80" and lens of reddish brown and gray mottled fat clay 88-90".	
			0.3		202		
			0.2		203		
			0.2		204		
22	205-215	0	NM		205	NO RECOVERY.	
					206		
					207		
					208		
					209		
					210		FS-EX-1D(210-212)072717 FS-DUP-072717
					211		
					212		
					213		
					214		
23	215-225	115	0.0	SP	215	0-41": POORLY GRADED SAND, fine sand, trace silt, brown.	FS-EX-1D(215-217)072817
			0.0		216		
			0.0		217		
			0.0	SM	218	41-85": SILTY SAND, fine sand, brown with lens of gray lean clay 64-70".	
			0.0		219		
			1.2	CH	220		
			0.0	SM	221		
			0.0		222		
			0.0	CL	223	85-97": LEAN CLAY, gray and red mottled.	
			0.0	ML	224	97-115": SILT, few fine sand, gray and red.	
24	225-235	113	0.0	ML	225	0-38": SILT, few fine sand, gray and red.	FS-EX-1D(225-227)072817
			0.0		226		
			0.0		227		
			0.0	ML-CL	228	38-57": SILTY CLAY, gray and red.	
			0.0		229		
			0.2	SM	230	57-76": SILTY SAND, fine sand, gray and red.	
			0.2		231		
			0.2	CH	232	76-97": SANDY FAT CLAY, gray and red.	
			0.7		233		
			0.7	SP	234	97-113": POORLY GRADED SAND, fine sand, trace silt, reddish brown.	

ENSAFE	Frost Street Sites Westbury, New York	Location ID: EX-1D Page 7 of 7

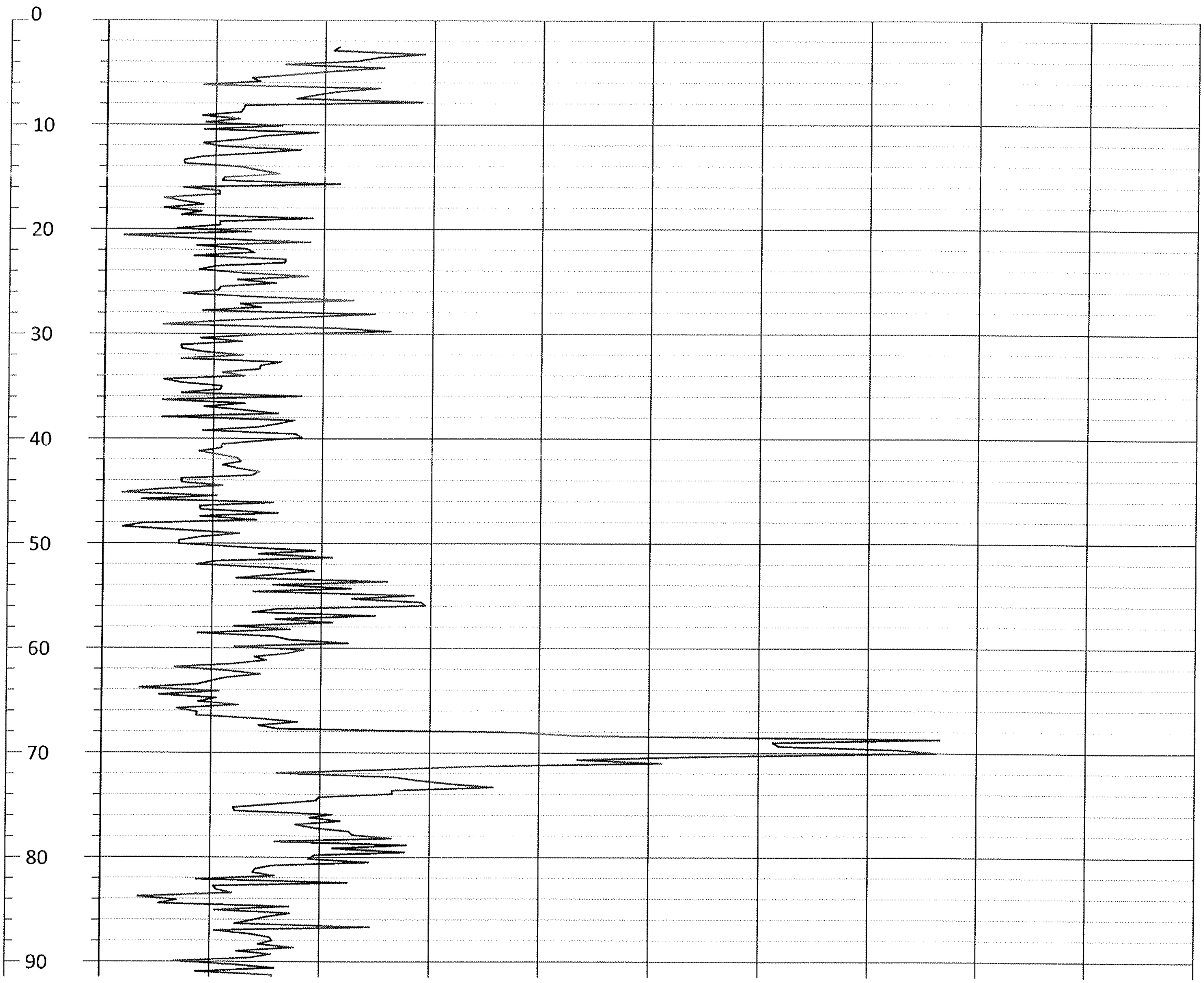
Sample Number	Sample Interval (FT)	Recovery (IN)	PID Reading (ppm)	USCS	Depth (FT)	Lithologic Description Visual-Manual Description (ASTM D 2488-06)	Analytical Sample
25	235-245	130	0.1	SP	**235**	0-33": POORLY GRADED SAND, fine sand, brown.	FS-EX-1D(235-237)072817
			0.6		**236**		
			0.6		**237**		
				SM		33-42": SILTY SAND, reddish brown.	
			0.6		**238**		FS-SOIL-EX-1D(238-239)072817
				CH		42-130": FAT CLAY, light brown (42-61") to black (61-130").	
			0.6		**239**		
			0.8		**240**		
			0.0		**241**		FS-SOIL-EX-1D(241)072817
			0.0		**242**		
			0.3		**243**		
			0.4		**244**		

End of Boring at 245 FT.

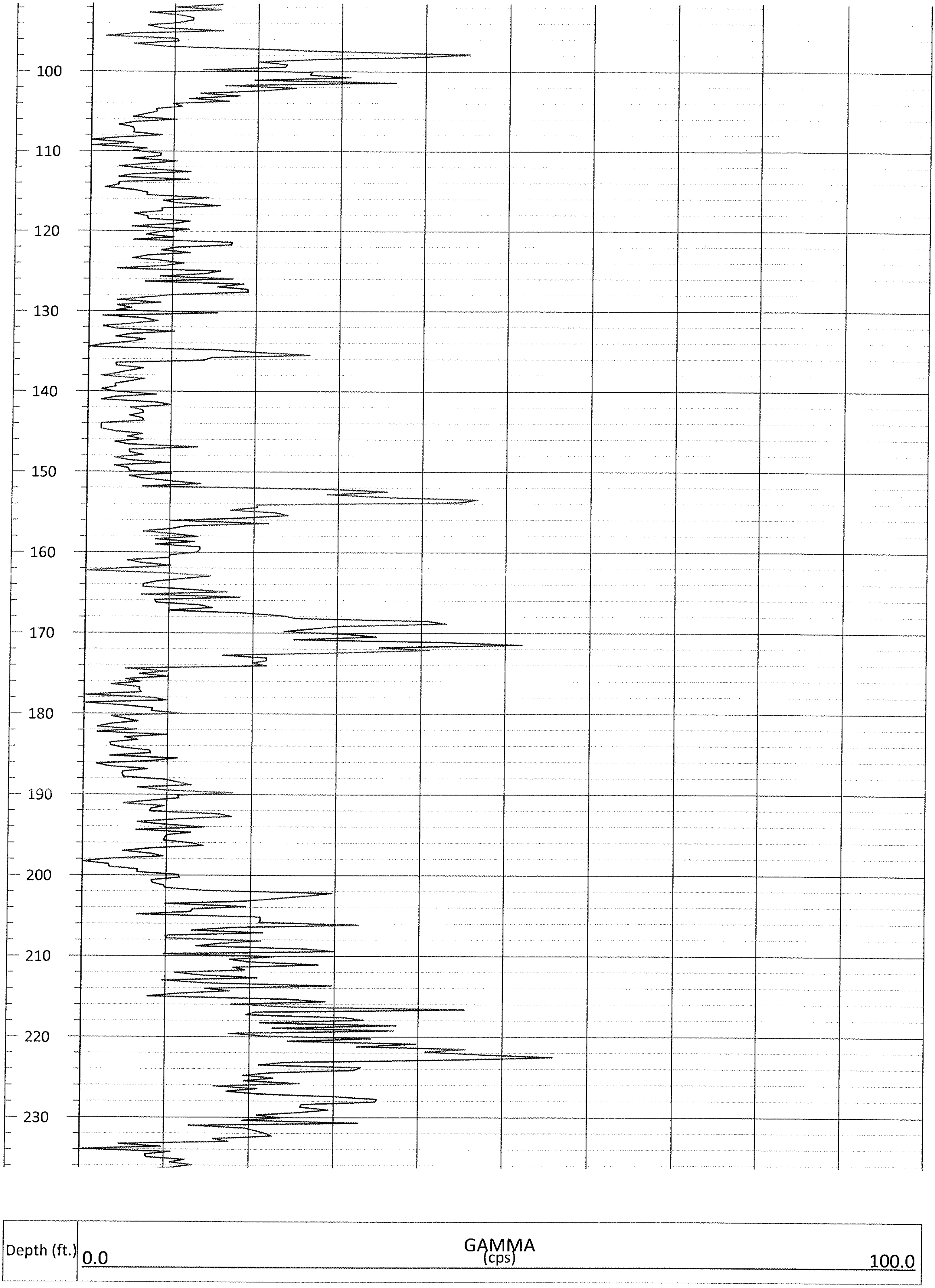
COMPANY:	DELTA WELL & PUMP CO., INC.
LOCATION:	century 21

Well: EX--1D	Depth Driller: Depth Logger:
Date: 07/31/17	Time:
	Logged by: RT
File Name: 8590	Witness: VIN

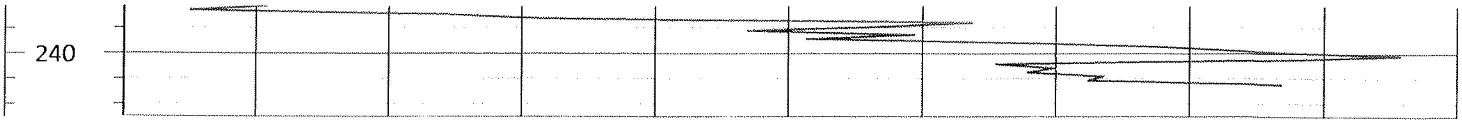
Depth (ft.)	0.0	GAMMA (cps)	100.0



Depth (ft.)	0.0	GAMMA (cps)	100.0



100
110
120
130
140
150
160
170
180
190
200
210
220
230
Depth (ft.)
GAMMA
(cps)
0.0
100.0



Depth (ft.)	0.0 GAMMA (cps) 100.0

Appendix B
Aquifer Conceptual Model

Appendix B. Schematic of Aquifer Conceptual Model, Frost Street

Depth (feet bgs)	Well Screen Inverval	MLU Layers	MF Layer	ground surface - 120 feet amsl	Thickness (feet)	Bottom (feet bgs)	Bottom (feet amsl)
10 20 30 40		1	1	EX-1 A, B, C, D WT	67	67	53
50 60	A (50-100)			Aquifer A-1 (SP, ML)			
70			2	**aquitard 1 (CL)**	6	73	47
80 90		2	3	Aquifer A-2 (SP, SM)	27	100	20
100 110 120 130 140	B (100-150)	3	4	Aquifer B (SP)	51	151	-31
150	C (150-200)		5	**aquitard 2 (CH, ML)**	4	155	-35
160 170 180 190		4	6	Aquifer C (SP)	45	200	-80
200 210 220	D (200-245)	5	7	Aquifer D (SM)	22	222	-102
230 240			8	**aquitard 3 (CH, CL, ML)**	23	245	-125
250 700		6	9	Magothy not to scale	455	700	-580

Notes:

Layer 1 contains water table at approximately 51 feet bgs during pumping tests.

Aquifer and aquitard layers labeled with predominant USCS sediment classification

Multi-Layer Unsteady state (MLU) model used to interpret aquifer parameters from pumping test data; parmeters used as initial parameters to update MF model.

Modflow (MF) model used to simulate pumping scenarios; updated using MLU model results and calibrated to site water levels.

A Group MWs are screened in MF Layers 1-3 (50-80 feet bgs)

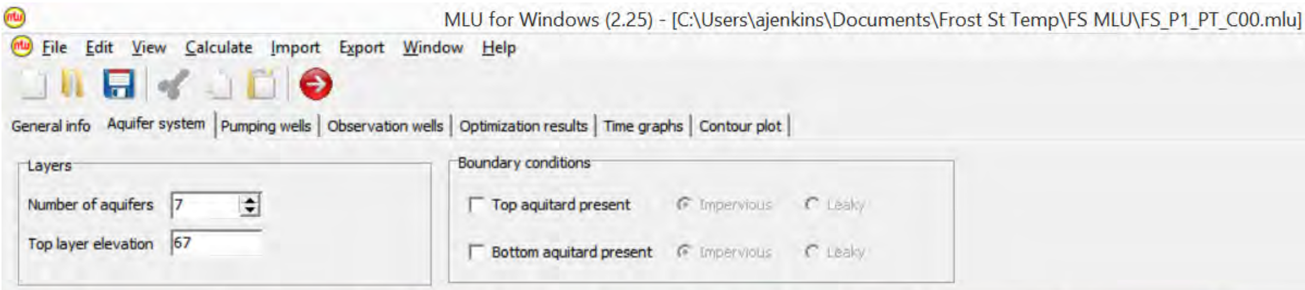
B Group MWs are screened in MF Layer 4 (119-149 feet bgs)

C Group MWs are screened in MF Layers 6 (159-184 feet bgs)

D Group MWs are screened in MF Layers 7-8 (221-249 feet bgs)

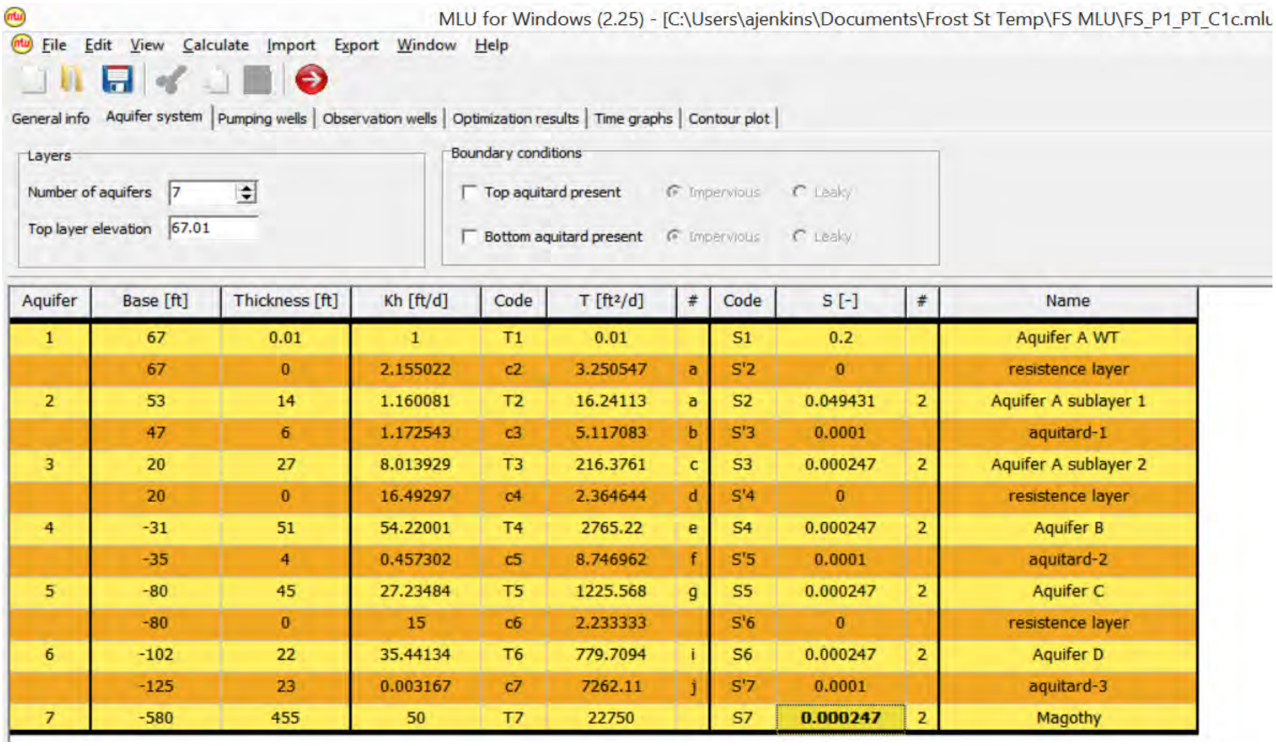
Appendix C
Model Assumptions, Parameters, and Properties

Figure C-1. Initial MLU Aquifer Parameters, Test T5



Aquifer	Base [ft]	Thickness [ft]	Kh [ft/d]	Code	T [ft²/d]	#	Code	S [-]	#	Name
1	66.99	0.01	0.0001	T1	1E-06	a	S1	0.2	1	Aquifer A WT
	66.99	0	0.05	c2	140.1	a	S'2	0		resistence layer
2	52.99	14	7.2	T2	100.8	a	S2	0.001	2	Aquifer A sublayer 1
	46.99	6	0.72	c3	8.333333	b	S'3	0.0001		aquitard-1
3	19.99	27	7.2	T3	194.4	c	S3	0.001	2	Aquifer A sublayer 2
	19.99	0	4.2	c4	9.285714	d	S'4	0		resistence layer
4	-31.01	51	42.5	T4	2167.5	e	S4	0.001	2	Aquifer B
	-35.01	4	0.3	c5	13.33333	f	S'5	0.0001		aquitard-2
5	-80.01	45	31.5	T5	1417.5	g	S5	0.001	2	Aquifer C
	-80.01	0	0.3	c6	111.6667	h	S'6	0		resistence layer
6	-102.01	22	27.6	T6	607.2	i	S6	0.001	2	Aquifer D
	-125.01	23	0.03	c7	766.6667		S'7	0.0001		aquitard-3
7	-580.01	455	50	T7	22750		S7	0.001	2	Magothy

Figure C-2. MLU Optimized Aquifer Parameters and Observed verses Simulated Curve Fit, Test T5



Aquifer	Base [ft]	Thickness [ft]	Kh [ft/d]	Code	T [ft²/d]	#	Code	S [-]	#	Name
1	67	0.01	1	T1	0.01		S1	0.2		Aquifer A WT
	67	0	2.155022	c2	3.250547	a	S'2	0		resistence layer
2	53	14	1.160081	T2	16.24113	a	S2	0.049431	2	Aquifer A sublayer 1
	47	6	1.172543	c3	5.117083	b	S'3	0.0001		aquitard-1
3	20	27	8.013929	T3	216.3761	c	S3	0.000247	2	Aquifer A sublayer 2
	20	0	16.49297	c4	2.364644	d	S'4	0		resistence layer
4	-31	51	54.22001	T4	2765.22	e	S4	0.000247	2	Aquifer B
	-35	4	0.457302	c5	8.746962	f	S'5	0.0001		aquitard-2
5	-80	45	27.23484	T5	1225.568	g	S5	0.000247	2	Aquifer C
	-80	0	15	c6	2.233333		S'6	0		resistence layer
6	-102	22	35.44134	T6	779.7094	i	S6	0.000247	2	Aquifer D
	-125	23	0.003167	c7	7262.11	j	S'7	0.0001		aquitard-3
7	-580	455	50	T7	22750		S7	0.000247	2	Magothy

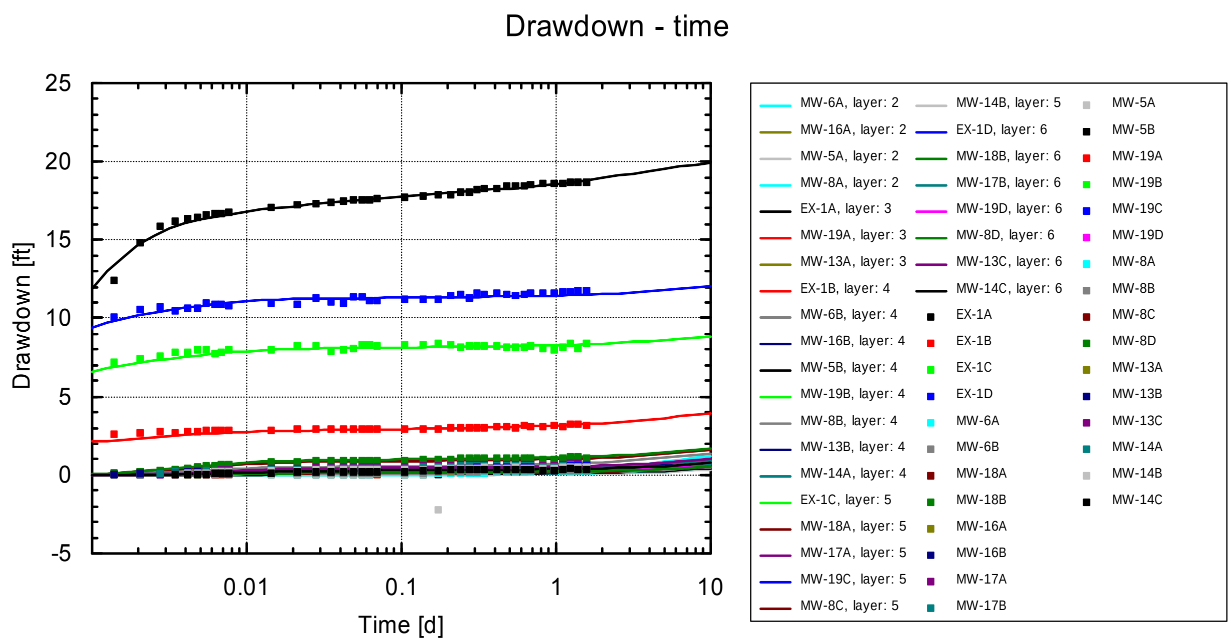
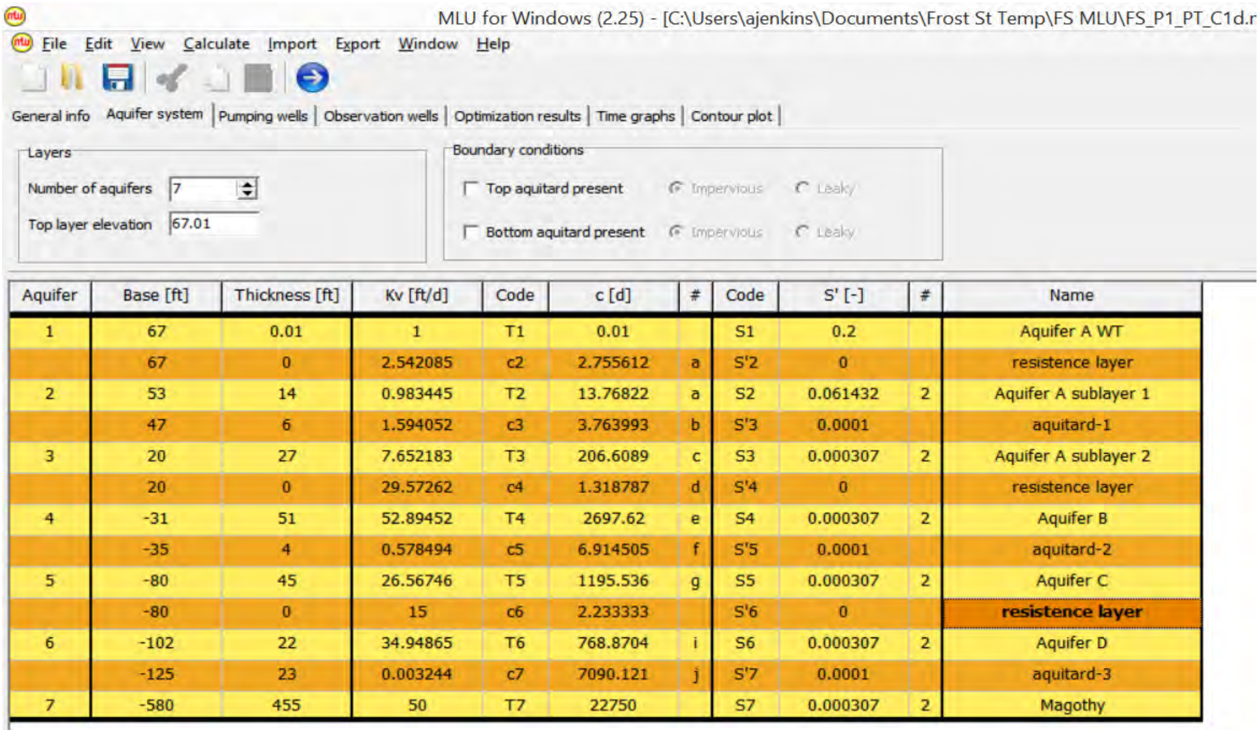
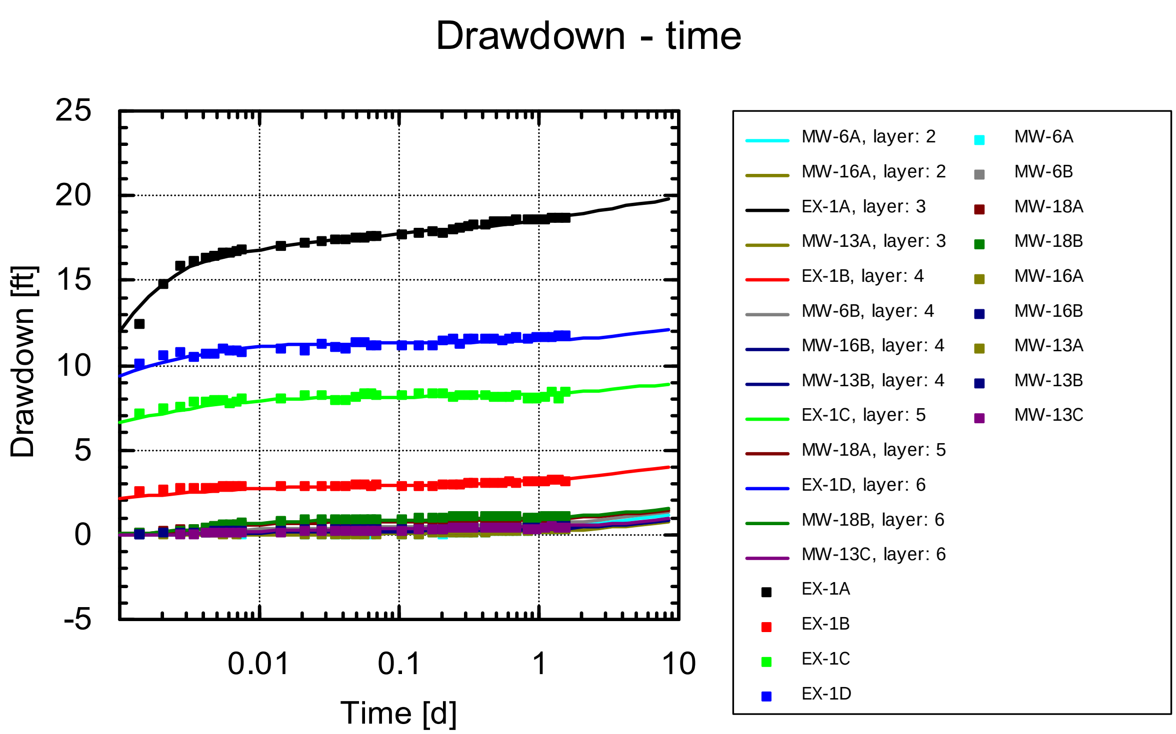


Figure C-3. MLU Optimized Aquifer Parameters and Observed verses Simulated Curve Fit, Test T5 Wells <300 feet

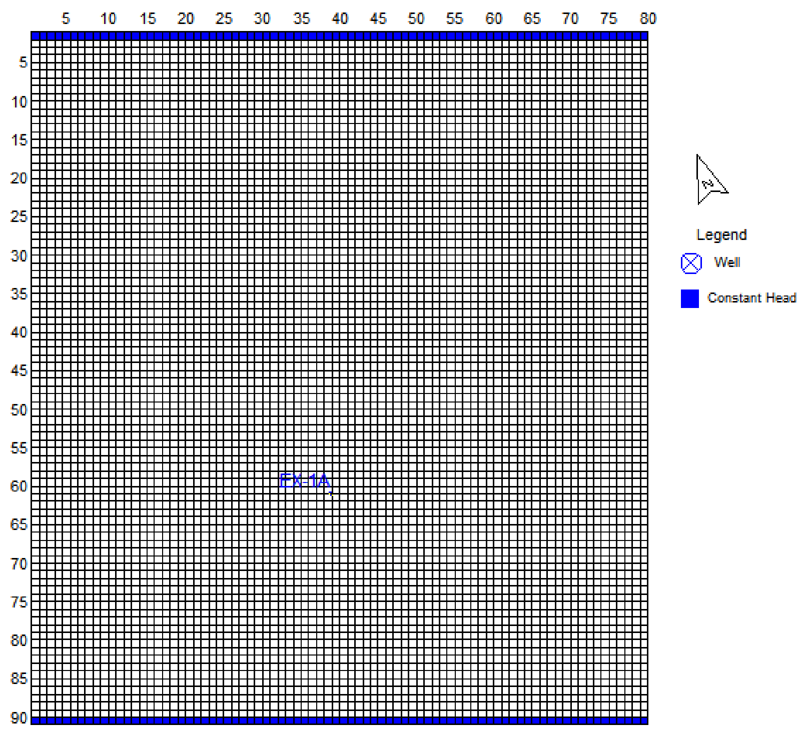


Aquifer	Base [ft]	Thickness [ft]	Kv [ft/d]	Code	c [d]	#	Code	S' [-]	#	Name
1	67	0.01	1	T1	0.01		S1	0.2		Aquifer A WT
	67	0	2.542085	c2	2.755612	a	S'2	0		resistence layer
2	53	14	0.983445	T2	13.76822	a	S2	0.061432	2	Aquifer A sublayer 1
	47	6	1.594052	c3	3.763993	b	S'3	0.0001		aquitard-1
3	20	27	7.652183	T3	206.6089	c	S3	0.000307	2	Aquifer A sublayer 2
	20	0	29.57262	c4	1.318787	d	S'4	0		resistence layer
4	-31	51	52.89452	T4	2697.62	e	S4	0.000307	2	Aquifer B
	-35	4	0.578494	c5	6.914505	f	S'5	0.0001		aquitard-2
5	-80	45	26.56746	T5	1195.536	g	S5	0.000307	2	Aquifer C
	-80	0	15	c6	2.233333		S'6	0		**resistence layer**
6	-102	22	34.94865	T6	768.8704	i	S6	0.000307	2	Aquifer D
	-125	23	0.003244	c7	7090.121	j	S'7	0.0001		aquitard-3
7	-580	455	50	T7	22750		S7	0.000307	2	Magothy

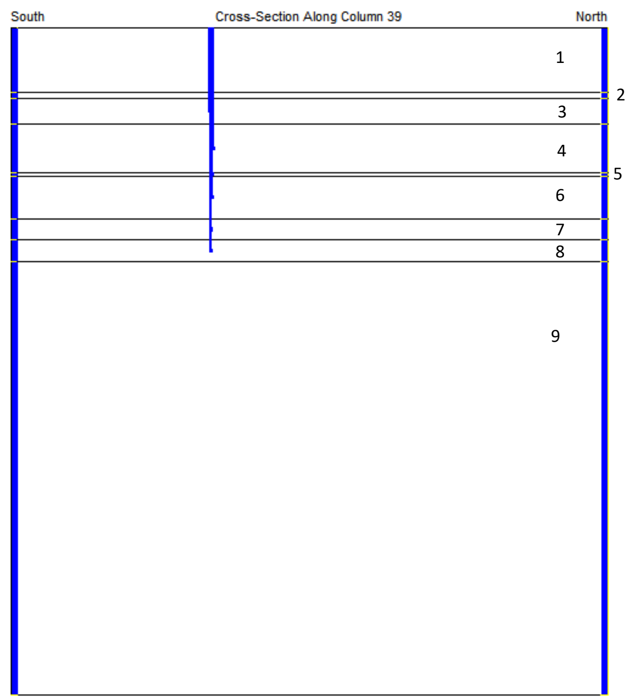


Appendix D
Baseline Model

Frost Street Site, Baseline Conditions, Calibrated Model with No Site Pumping



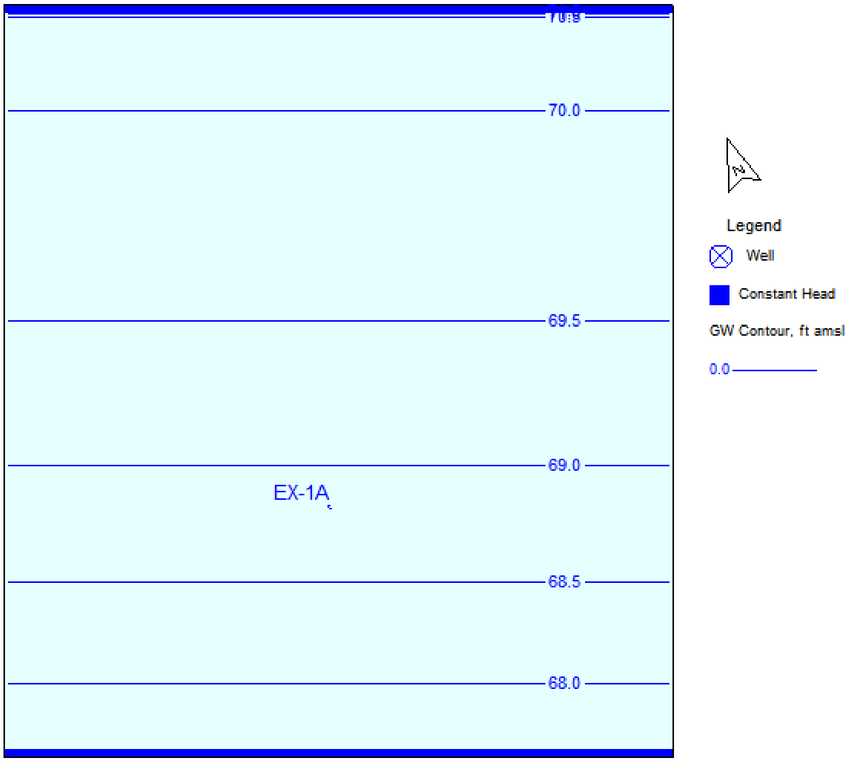
Model domain (4,000 x 4,500 ft) and grid showing cells (50 x 50 ft); up- and down-gradient constant head boundaries shown.



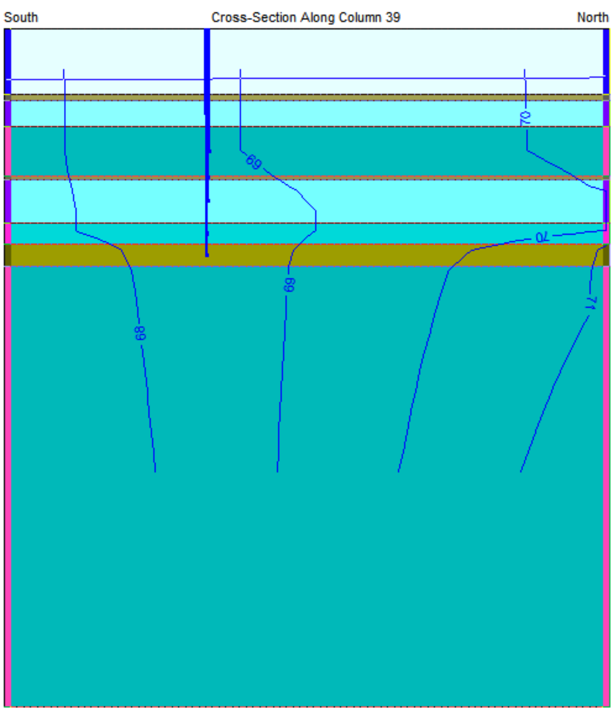
Model Layers 1-9

Cross section (up- to down-gradient) through EX-1 location; model layers 1-9 shown.

Frost Street Site, Baseline Conditions, Calibrated Model with No Site Pumping



Layer 1 potentiometric surface (water table) – no EX-1 pumping



EX-1A well = Layers 1, 2 & 3 (lgt blue)

EX-1B well = Layer 4 (dk blue)

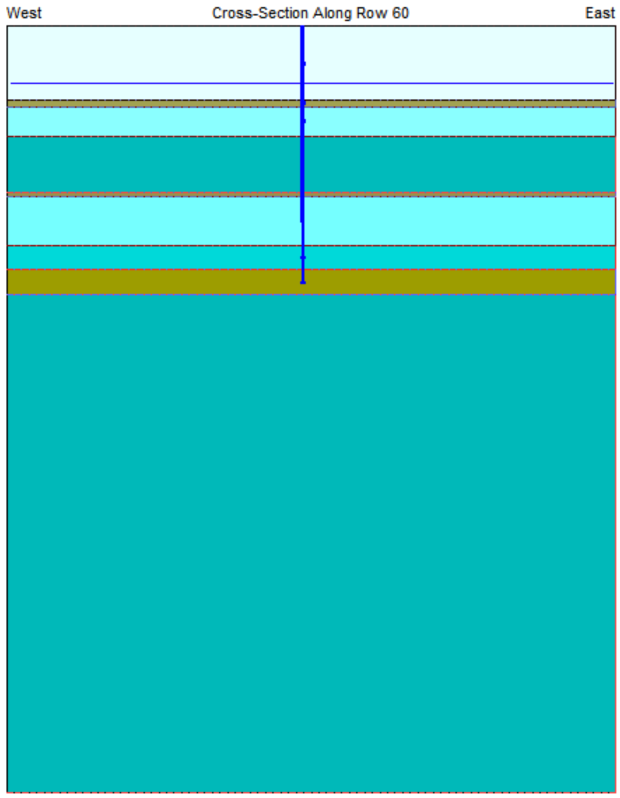
EX-1C well = Layer 6 (lgt blue)

EX-1D well = Layers 7 and 8 (med blue)

Olive layers 2, 5, 8 are silt/clay aquitard zones

Cross section (up- to down-gradient) through EX-1 locations with no pumping. Blue shading indicates relative layer conductivity K (darker shades = increase in K); olive shading indicates lower K clay zones.

Frost Street Site, Baseline Conditions, Calibrated Model with No Site Pumping



Cross section (west - east) through EX-1 locations with no pumping. Blue shading indicates relative layer conductivity K (darker shades = increase in K); olive shading indicates lower K aquitard zones. Groundwater flow is out of page.

Frost Street Site, Baseline Conditions, Calibrated Model with No Site Pumping

FS Model R5r2 Pest Calibration:

Initial Run for Recharge and CHs (zones selected based on previous sensitivity analysis)

PEST Parameters

	Type	Use	Zone	Minimum	Maximum	Transform	Limit
1	Recharge	☑	1	5.50000e-004	2.20000e-003	None	Factor
2	CH	☑	4	70.00	73.00	None	Factor
3	CH	☑	5	70.00	73.00	None	Factor
4	CH	☑	6	70.00	73.00	None	Factor
5	CH	☑	7	70.00	73.00	None	Factor
6	CH	☑	14	65.00	69.00	None	Factor
7	CH	☑	19	65.00	69.00	None	Factor
8	None	☐	1	2.98	298.10	Log	Factor
9	None	☐	1	5.80000e-003	5.80000e-001	Log	Factor
10	None	☐	1	1.50	150.00	Log	Factor
11	None	☐	1	1.50	150.00	Log	Factor
12	None	☐	1	2.54011e-003	2.54011e-001	Log	Factor
13	None	☐	1	2.98	298.10	Log	Factor
14	None	☐	1	5.80000e-002	5.80	Log	Factor

Copy to Clipboard | Paste | All Log/Factor | Parameter Setup | Clear All Parameters

OK | Cancel

single point

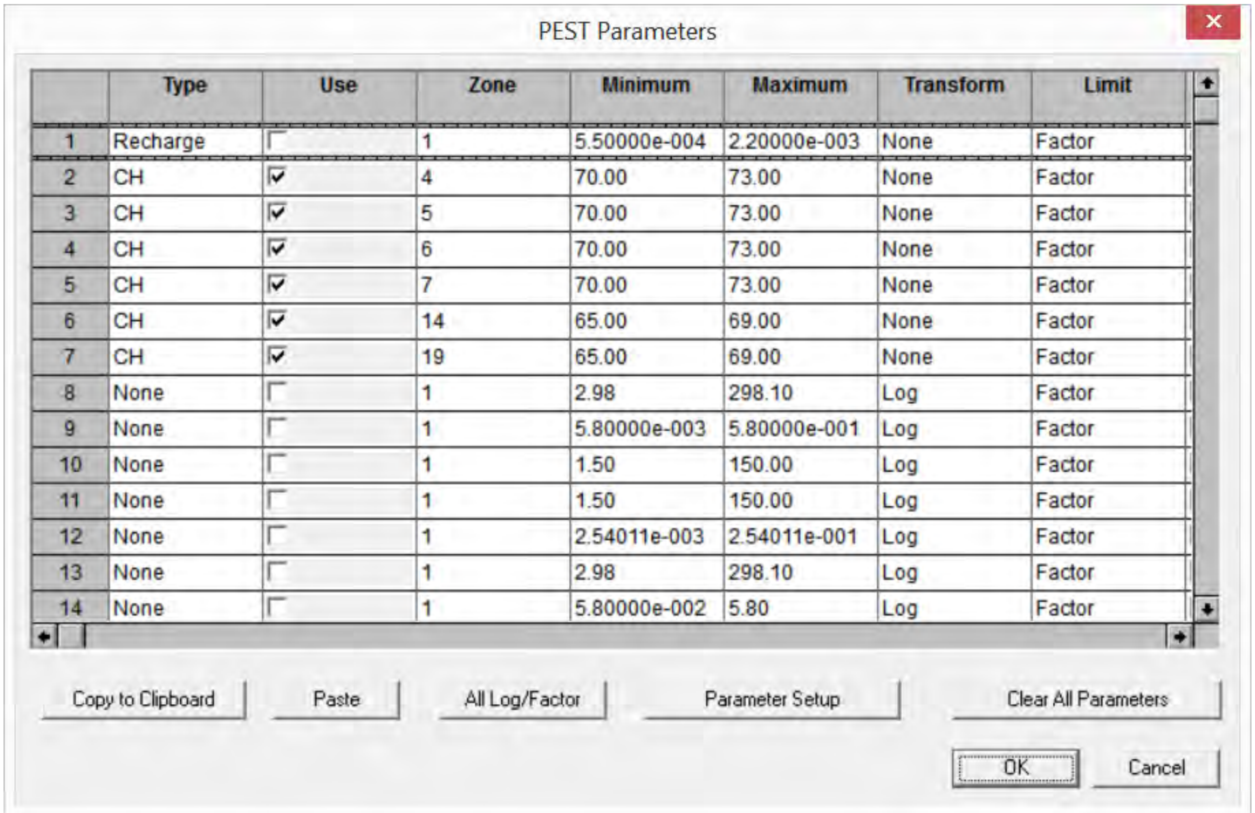
r1	5.5000000000000000E-04	1.000000	0.000000
ch4	70.0000000000000	1.000000	0.000000
ch5	70.0000000000000	1.000000	0.000000
ch6	70.0000000000000	1.000000	0.000000
ch7	70.2019101590000	1.000000	0.000000
ch14	67.5621301930000	1.000000	0.000000
ch19	66.74626089100002	1.000000	0.000000

Sensitivity

r1	78.184000
ch4	0.033612
ch5	0.000026
ch6	0.014890
ch7	0.009583
ch14	0.058918
ch19	0.040057

Frost Street Site, Baseline Conditions, Calibrated Model with No Site Pumping

Re Run Pest for CHs only (to 'see' sensitivity of CHs):



PEST Parameters

	Type	Use	Zone	Minimum	Maximum	Transform	Limit
1	Recharge	☐	1	5.50000e-004	2.20000e-003	None	Factor
2	CH	☑	4	70.00	73.00	None	Factor
3	CH	☑	5	70.00	73.00	None	Factor
4	CH	☑	6	70.00	73.00	None	Factor
5	CH	☑	7	70.00	73.00	None	Factor
6	CH	☑	14	65.00	69.00	None	Factor
7	CH	☑	19	65.00	69.00	None	Factor
8	None	☐	1	2.98	298.10	Log	Factor
9	None	☐	1	5.80000e-003	5.80000e-001	Log	Factor
10	None	☐	1	1.50	150.00	Log	Factor
11	None	☐	1	1.50	150.00	Log	Factor
12	None	☐	1	2.54011e-003	2.54011e-001	Log	Factor
13	None	☐	1	2.98	298.10	Log	Factor
14	None	☐	1	5.80000e-002	5.80	Log	Factor

Copy to Clipboard | Paste | All Log/Factor | Parameter Setup | Clear All Parameters

OK | Cancel

single point

ch4	70.00000000000000	1.000000	0.000000
ch5	70.00000000000000	1.000000	0.000000
ch6	70.00000000000000	1.000000	0.000000
ch7	70.00000000000000	1.000000	0.000000
ch14	67.59530782800000	1.000000	0.000000
ch19	66.75238904000000	1.000000	0.000000

Sensitivity

ch4	0.033617
ch5	0.000031
ch6	0.014890
ch7	0.009573
ch14	0.057523
ch19	0.040044

Import these changes and re-run model; new calibration stats below:

Frost Street Site, Baseline Conditions, Calibrated Model with No Site Pumping

Target Statistics

Target	Residual	Name
68.18	0.12	14C
68.21	0.00	13C
68.43	-0.27	14B
68.46	-0.59	17B
68.47	-0.47	EX-1D
68.48	-0.29	18B
68.51	-0.54	17A
68.56	-0.15	14A

Residual Mean = -0.22
Residual Standard Dev. = 0.19
Absolute Residual Mean = 0.23

Residual Sum of Squares =2.33e+000
RMS Error =0.29

Minimum Residual = -0.59
Maximum Residual = 0.12
Range of Observations = 0.94

Scaled Res. Std. Dev. = 0.199
Scaled Abs. Mean = 0.246
Scaled RMS = 0.307

Number of Observations = 28

Close

****

Re Run Pest for Recharge only:

PEST Parameters

	Type	Use	Zone	Minimum	Maximum	Transform	Limit
1	Recharge	☑	1	5.50000e-004	2.20000e-003	None	Factor
2	None	☐	1	5.28900e-001	52.89	Log	Factor
3	None	☐	1	5.80000e-002	5.80	Log	Factor
4	None	☐	1	4.26	426.21	Log	Factor
5	None	☐	1	3.50	349.50	Log	Factor
6	None	☐	1	3.00000e-004	3.00000e-002	Log	Factor
7	None	☐	1	2.98	298.10	Log	Factor
8	None	☐	1	2.98	298.10	Log	Factor
9	None	☐	1	5.80000e-003	5.80000e-001	Log	Factor
10	None	☐	1	1.50	150.00	Log	Factor
11	None	☐	1	1.50	150.00	Log	Factor
12	None	☐	1	2.54011e-003	2.54011e-001	Log	Factor
13	None	☐	1	2.98	298.10	Log	Factor
14	None	☐	1	5.80000e-002	5.80	Log	Factor

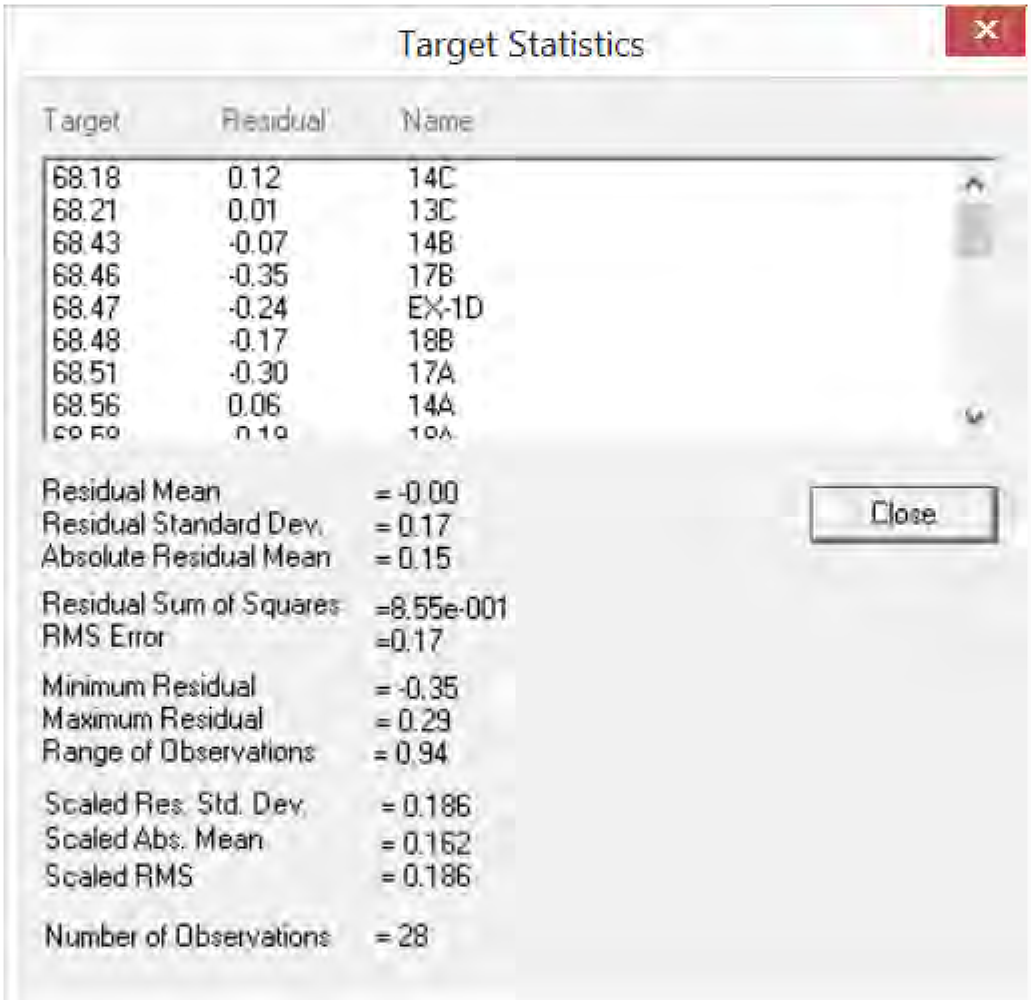
Copy to Clipboard | Paste | All Log/Factor | Parameter Setup | Clear All Parameters single point

r1 5.5000000000000000E-04 1.000000 0.000000

Sensitivity

r1 78.614700

New calibration stats below:



Pest calibration shows improvement by lowering aerial Recharge from 4.82 "/yr down to 2.41"/yr; this value seems low but plausible for highly developed area with mostly roofs and paved surfaces, and few recharge areas.

Decide not to accept change to Recharge at this time, will run Kx and Kz first.

Frost Street Site, Baseline Conditions, Calibrated Model with No Site Pumping

Re run Pest to assess Kx and Kx in zones shown in previous sensitivity analysis for model R5 to be most sensitive.

PEST Parameters

	Type	Use	Zone	Minimum	Maximum	Transform	Limit
1	Kx	☑	4	5.29	528.90	Log	Factor
2	Kx	☑	5	5.80000e-002	5.80	Log	Factor
3	Kx	☑	6	2.66	265.70	Log	Factor
4	Kx	☑	7	3.50	349.50	Log	Factor
5	Kz	☑	7	1.50	150.00	Log	Factor
6	Kz	☑	8	3.00000e-004	3.00000e-002	Log	Factor
7	None	☐	1	2.98	298.10	Log	Factor
8	None	☐	1	2.98	298.10	Log	Factor
9	None	☐	1	5.80000e-003	5.80000e-001	Log	Factor
10	None	☐	1	1.50	150.00	Log	Factor
11	None	☐	1	1.50	150.00	Log	Factor
12	None	☐	1	2.54011e-003	2.54011e-001	Log	Factor
13	None	☐	1	2.98	298.10	Log	Factor
14	None	☐	1	5.80000e-002	5.80	Log	Factor

Copy to Clipboard | Paste | All Log/Factor | Parameter Setup | Clear All Parameters

OK | Cancel

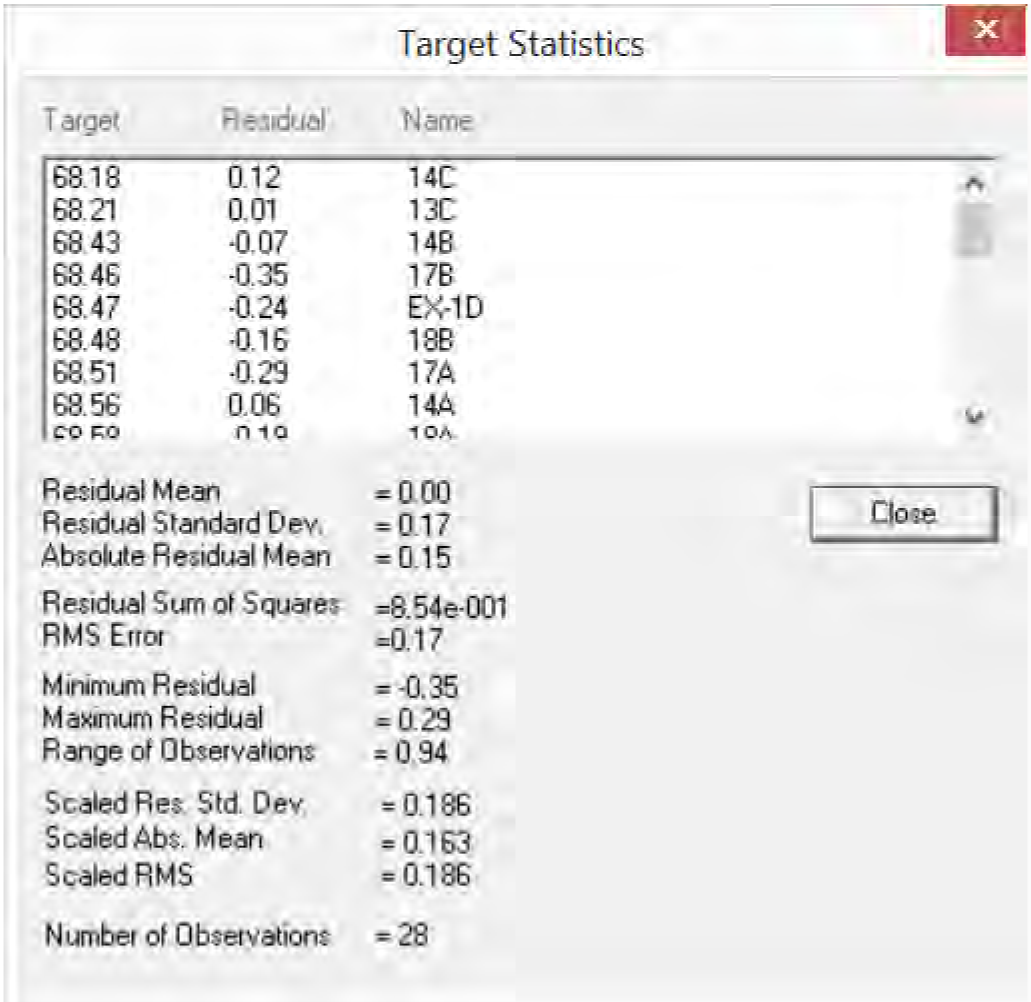
single point

kx4	49.56641920800000	1.000000	0.000000
kx5	0.5779593487900000	1.000000	0.000000
kx6	31.24267928700000	1.000000	0.000000
kx7	38.83053077300000	1.000000	0.000000
kz7	15.07997519400000	1.000000	0.000000
kz8	2.8175438400000000E-03	1.000000	0.000000

Sensitivity

kx4	0.065150
kx5	0.003203
kx6	0.034766
kx7	0.022028
kz7	0.000834
kz8	0.009837

Frost Street Site, Baseline Conditions, Calibrated Model with No Site Pumping



Based on above relative insensitivity to changes in Kx or Kz, and the negligible improvement in calibration statistics, I will not update Kx/Kz parameter values.

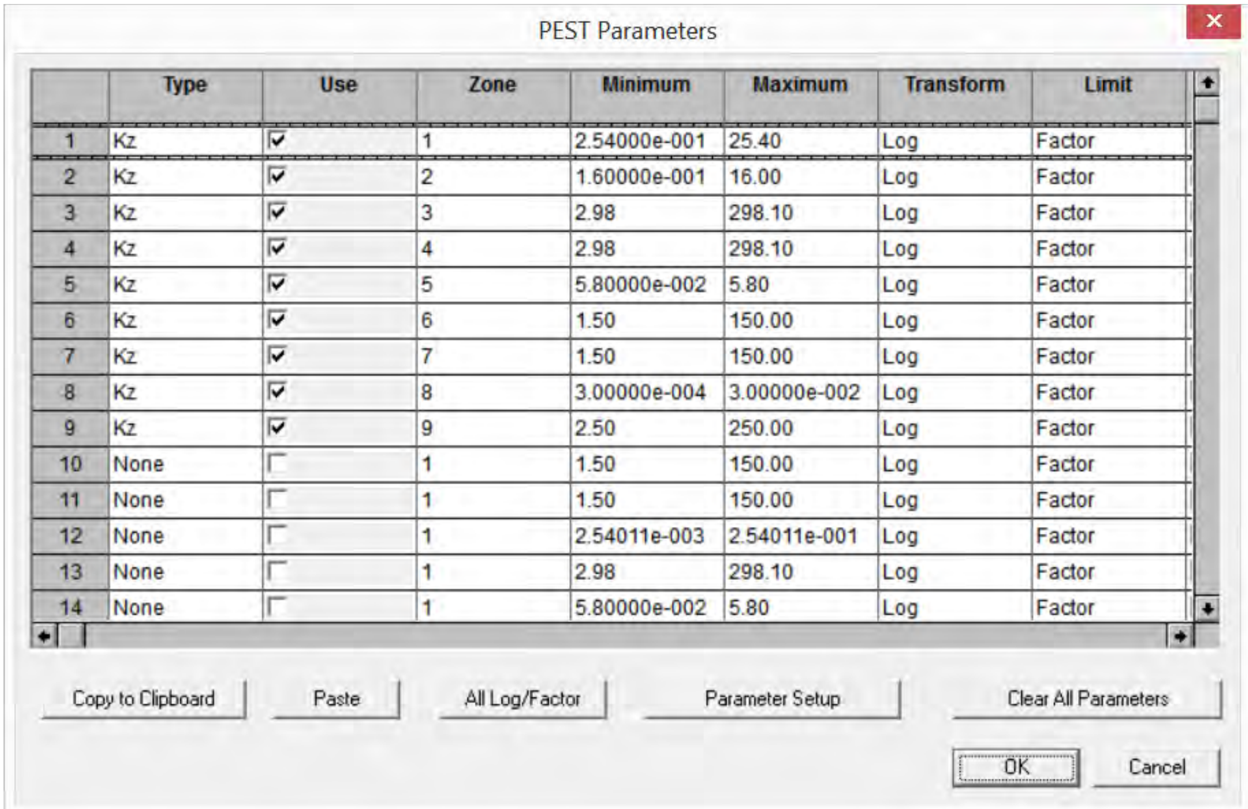
****

Run Pest for Kx in all zones (using 0.1 and 10 as multiplier range) as check; no improvement in calibration stats, do not update.

****

Run Pest for Kz in all zones (using 0.1 and 10 as multiplier range) as check.

Frost Street Site, Baseline Conditions, Calibrated Model with No Site Pumping



	Type	Use	Zone	Minimum	Maximum	Transform	Limit
1	Kz	☑	1	2.54000e-001	25.40	Log	Factor
2	Kz	☑	2	1.60000e-001	16.00	Log	Factor
3	Kz	☑	3	2.98	298.10	Log	Factor
4	Kz	☑	4	2.98	298.10	Log	Factor
5	Kz	☑	5	5.80000e-002	5.80	Log	Factor
6	Kz	☑	6	1.50	150.00	Log	Factor
7	Kz	☑	7	1.50	150.00	Log	Factor
8	Kz	☑	8	3.00000e-004	3.00000e-002	Log	Factor
9	Kz	☑	9	2.50	250.00	Log	Factor
10	None	☐	1	1.50	150.00	Log	Factor
11	None	☐	1	1.50	150.00	Log	Factor
12	None	☐	1	2.54011e-003	2.54011e-001	Log	Factor
13	None	☐	1	2.98	298.10	Log	Factor
14	None	☐	1	5.80000e-002	5.80	Log	Factor

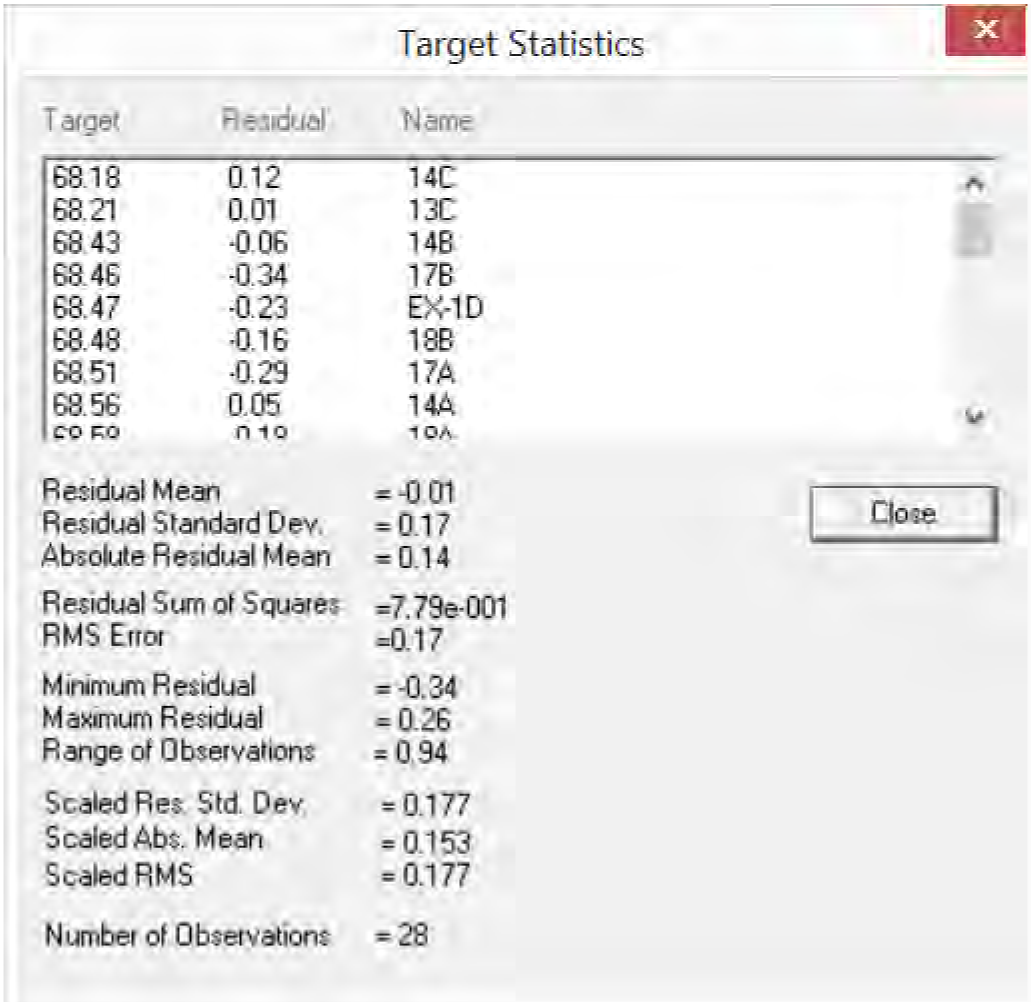
single point

kz1	25.4000000000000	1.000000	0.000000
kz2	0.160000000000000	1.000000	0.000000
kz3	298.100000000000	1.000000	0.000000
kz4	2.98100000000000	1.000000	0.000000
kz5	5.800000000000000E-02	1.000000	0.000000
kz6	1.50000000000000	1.000000	0.000000
kz7	150.000000000000	1.000000	0.000000
kz8	2.864830920000000E-03	1.000000	0.000000
kz9	250.000000000000	1.000000	0.000000

Sensitivity

kz1	0.000268
kz2	0.002580
kz3	0.000336
kz4	0.001132
kz5	0.002701
kz6	0.000849
kz7	0.000374
kz8	0.001170
kz9	0.000331

Frost Street Site, Baseline Conditions, Calibrated Model with No Site Pumping



See small improvement in calibration stats with KZs for zones 2, 5, and 8 being most sensitive. But note that several Kz values in several zones hit bottom end of range (yellow highlight); however, only zones 2 and 5 that hit min are sensitive and indicate need to be lower (zone 8 did not hit min/max).

Will lower minimum limit for zones 2 and 5 another order of mag and run Pest again.

Frost Street Site, Baseline Conditions, Calibrated Model with No Site Pumping

PEST Parameters

	Type	Use	Zone	Minimum	Maximum	Transform	Limit
1	Kz	☑	1	2.54000e-001	25.40	Log	Factor
2	Kz	☑	2	1.60000e-002	16.00	Log	Factor
3	Kz	☑	3	2.98	298.10	Log	Factor
4	Kz	☑	4	2.98	298.10	Log	Factor
5	Kz	☑	5	5.80000e-003	5.80	Log	Factor
6	Kz	☑	6	1.50	150.00	Log	Factor
7	Kz	☑	7	1.50	150.00	Log	Factor
8	Kz	☑	8	3.00000e-004	3.00000e-002	Log	Factor
9	Kz	☑	9	2.50	250.00	Log	Factor
10	None	☐	1	1.50	150.00	Log	Factor
11	None	☐	1	1.50	150.00	Log	Factor
12	None	☐	1	2.54011e-003	2.54011e-001	Log	Factor
13	None	☐	1	2.98	298.10	Log	Factor
14	None	☐	1	5.80000e-002	5.80	Log	Factor

Copy to Clipboard | Paste | All Log/Factor | Parameter Setup | Clear All Parameters

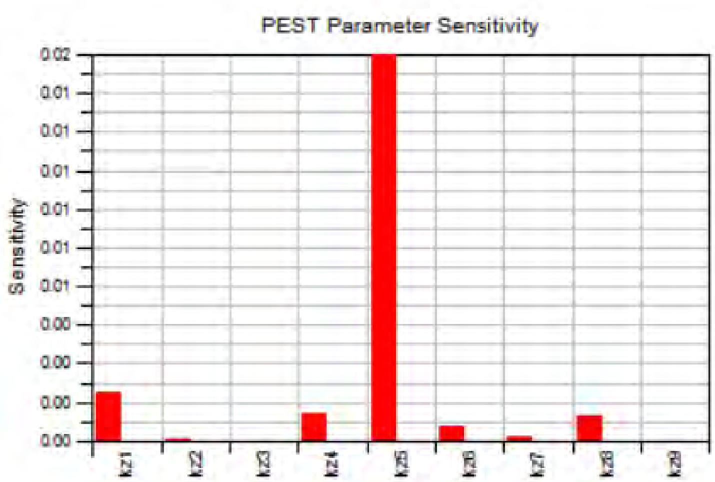
OK | Cancel

single point

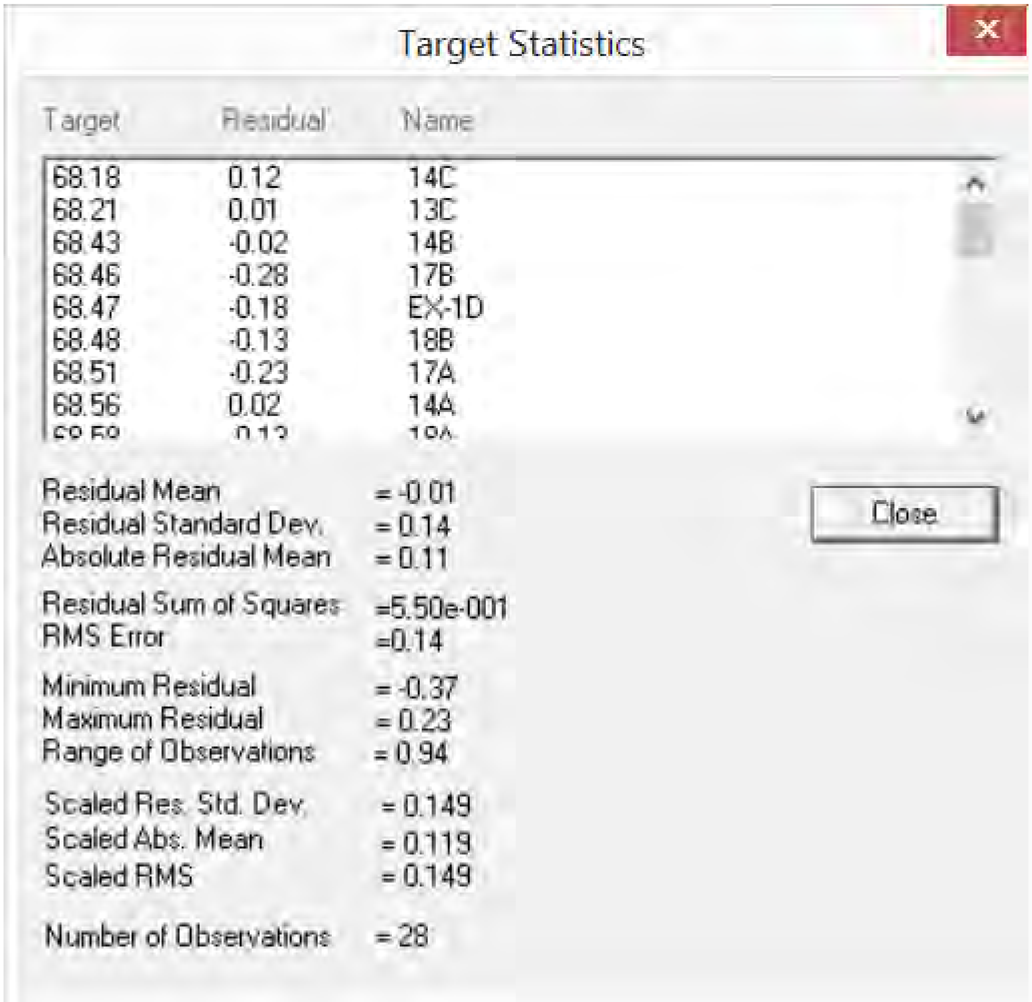
kz1	0.3776336852700000	1.000000	0.000000
kz2	16.00000000000000	1.000000	0.000000
kz3	298.1000000000000	1.000000	0.000000
kz4	2.981000000000000	1.000000	0.000000
kz5	5.8000000000000000E-03	1.000000	0.000000
kz6	1.500000000000000	1.000000	0.000000
kz7	1.500000000000000	1.000000	0.000000
kz8	1.0294964300000000E-03	1.000000	0.000000
kz9	178.2654893000000	1.000000	0.000000

Sensitivity

kz1	0.001880
kz2	0.000087
kz3	0.000012
kz4	0.001050
kz5	0.015233
kz6	0.000596
kz7	0.000137
kz8	0.001021
kz9	0.000001



Frost Street Site, Baseline Conditions, Calibrated Model with No Site Pumping



Based on above improvements in Cal Stats, will run Pest again only for most sensitive Kz zone 5. Because zones 5 hit min bound, will also lower min 1 order magnitude, see below:

Frost Street Site, Baseline Conditions, Calibrated Model with No Site Pumping

PEST Parameters

	Type	Use	Zone	Minimum	Maximum	Transform	Limit
1	Kz	☐	1	2.54000e-001	25.40	Log	Factor
2	Kz	☐	2	1.60000e-002	16.00	Log	Factor
3	Kz	☐	3	2.98	298.10	Log	Factor
4	Kz	☐	4	2.98	298.10	Log	Factor
5	Kz	☑	5	5.80000e-004	5.80	Log	Factor
6	Kz	☐	6	1.50	150.00	Log	Factor
7	Kz	☐	7	1.50	150.00	Log	Factor
8	Kz	☐	8	3.00000e-004	3.00000e-002	Log	Factor
9	Kz	☐	9	2.50	250.00	Log	Factor
10	None	☐	1	1.50	150.00	Log	Factor
11	None	☐	1	1.50	150.00	Log	Factor
12	None	☐	1	2.54011e-003	2.54011e-001	Log	Factor
13	None	☐	1	2.98	298.10	Log	Factor
14	None	☐	1	5.80000e-002	5.80	Log	Factor

Copy to Clipboard | Paste | All Log/Factor | Parameter Setup | Clear All Parameters

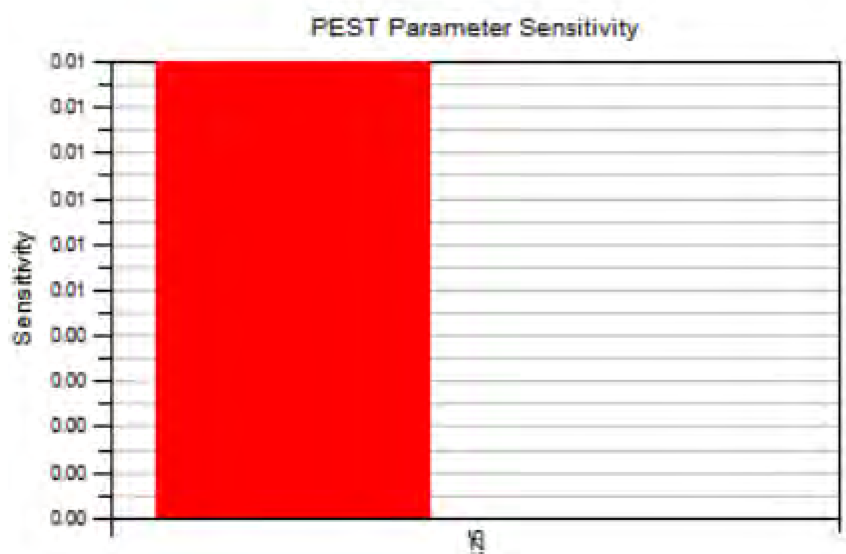
OK | Cancel

single point

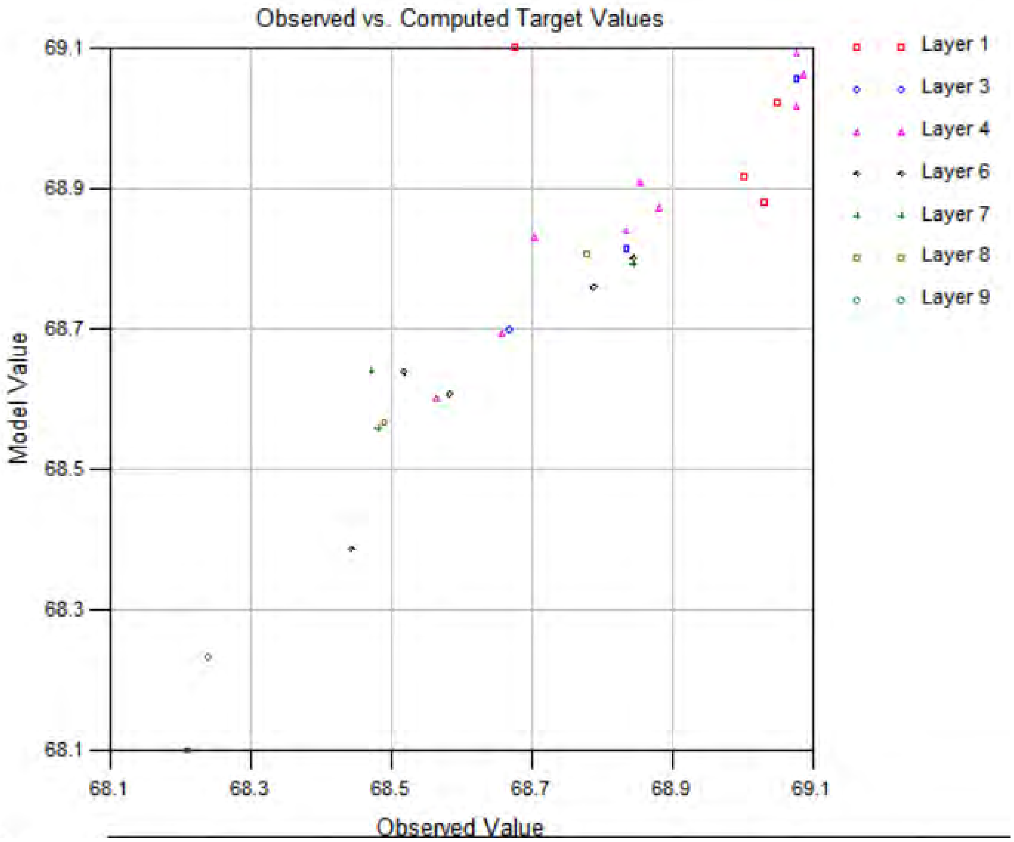
kz5 6.3225540999999992E-04 1.000000 0.000000

Sensitivity

kz5 0.012048



Frost Street Site, Baseline Conditions, Calibrated Model with No Site Pumping



Target Statistics

Target	Residual	Name
68.18	0.12	14C
68.21	0.01	13C
68.43	0.06	14B
68.46	-0.18	17B
68.47	-0.08	EX-1D
68.48	-0.08	18B
68.51	-0.13	17A
68.56	-0.04	14A

Residual Mean = -0.02
Residual Standard Dev. = 0.11
Absolute Residual Mean = 0.07

Residual Sum of Squares =3.64e-001
RMS Error =0.11

Minimum Residual = -0.46
Maximum Residual = 0.16
Range of Observations = 0.94

Scaled Res. Std. Dev. = 0.119
Scaled Abs. Mean = 0.078
Scaled RMS = 0.121

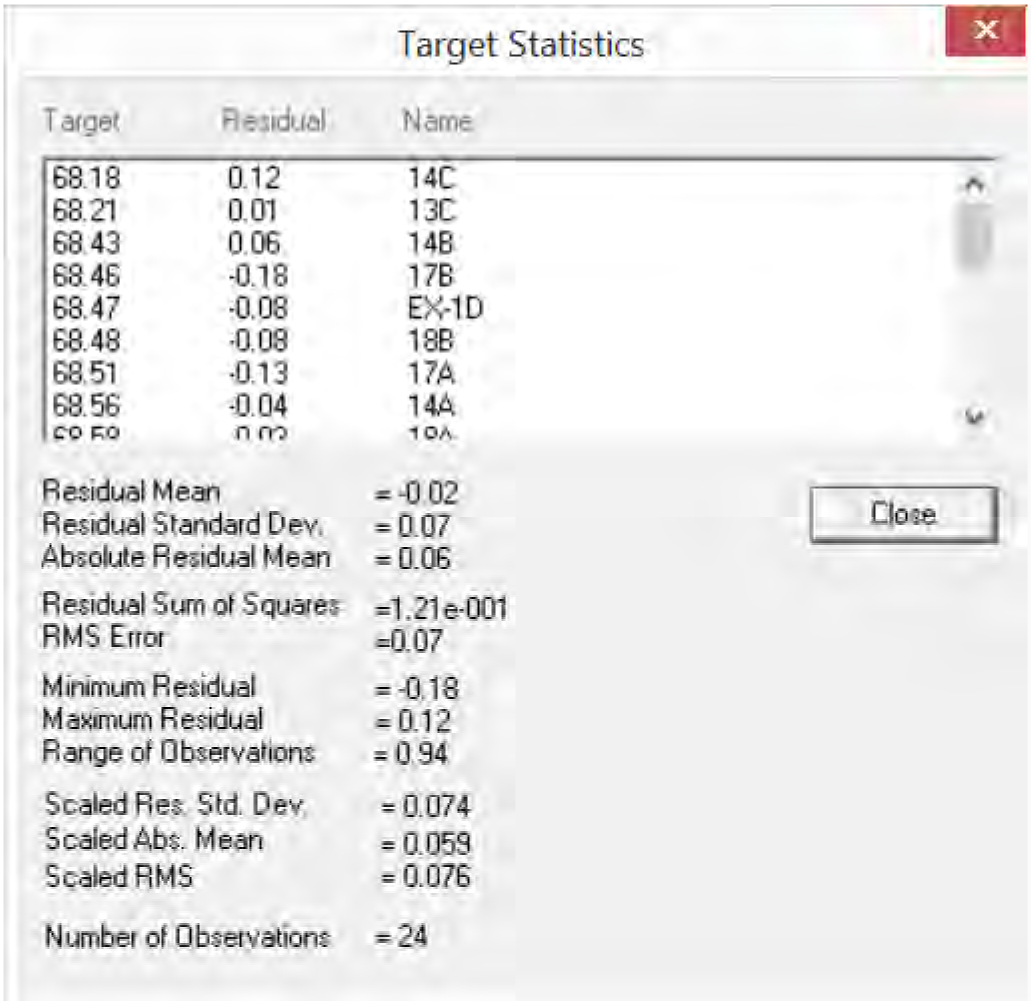
Number of Observations = 28

Close

Frost Street Site, Baseline Conditions, Calibrated Model with No Site Pumping

Cal stats improved significantly; Pest change to Kz in zone 5 is very low, but plausible value.

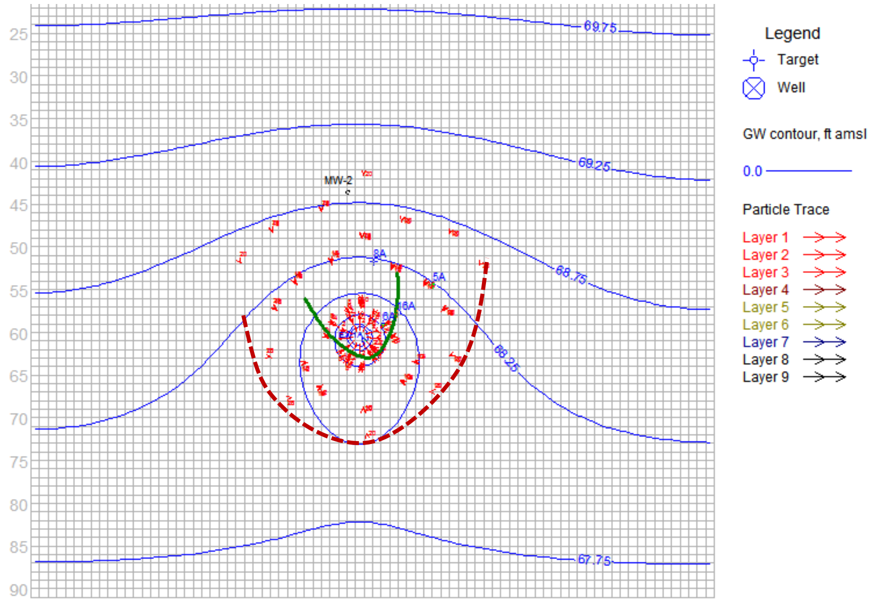
Therefore, accept Pest changes, save, and re run model SSR5r2. As shown above, scaled errors are all less than 12%, which indicates a reasonable calibration. Note that residual for well MW-8A is order of mag higher than all other wells; this suggests an anomalous reading for the well. Calibration stats shown below for Layers 2-9 (leaving out Layer 1 with MW-8A) show improvement and scaled error less than 10% indicating good calibration.



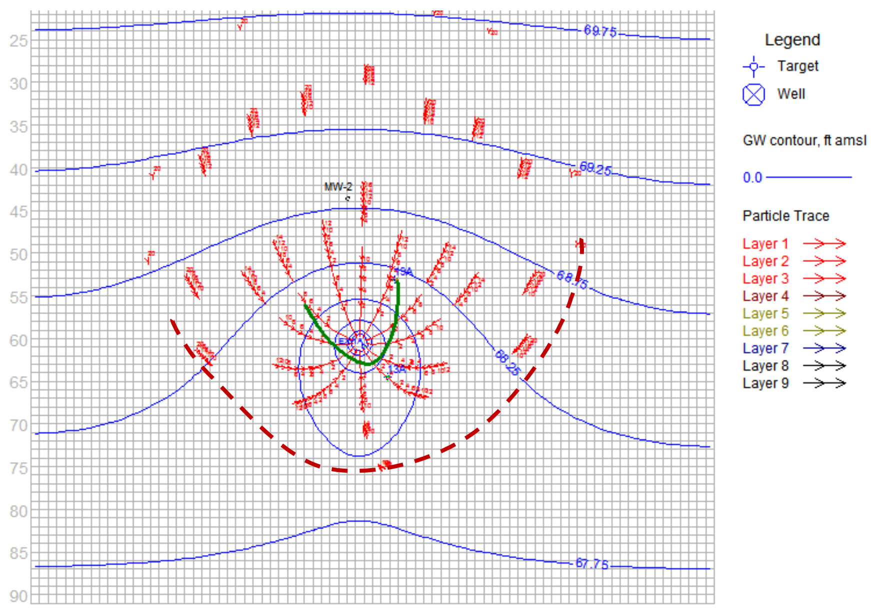
Appendix E
Particle Traces and Capture Zones

Appendix E - Design Rates

Model Layer 1, Well EX-1A1 (upper aquifer layer):



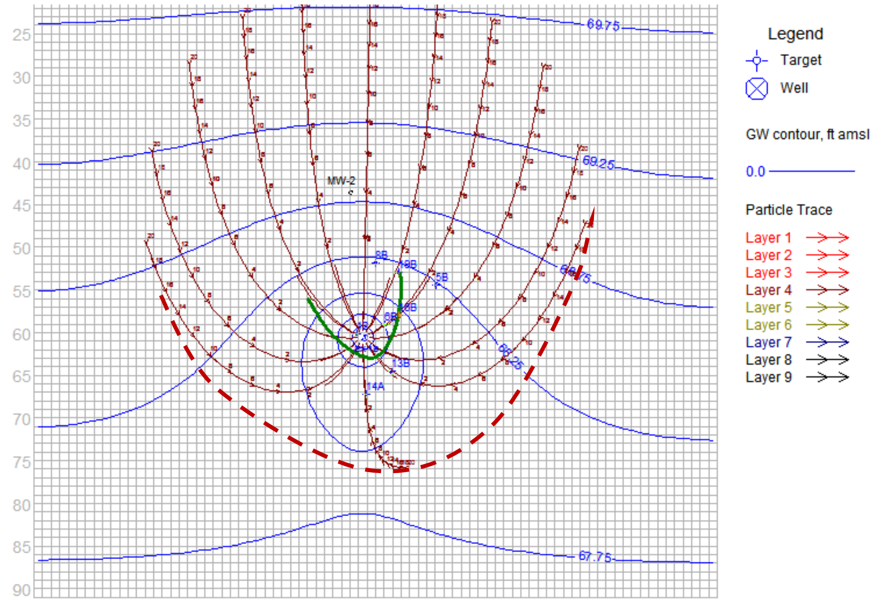
Model Layer 3, Well EX-1A2 (lower aquifer layer):



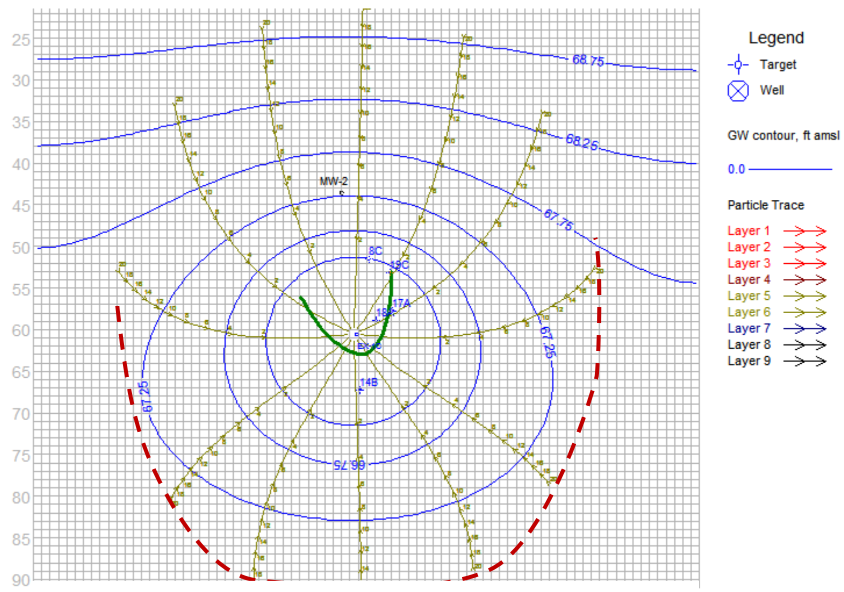
Notes: Green = Required Capture Zone
Red = Calculated Capture Zone

Appendix E - Design Rates

Model Layer 4, Well EX-1B:



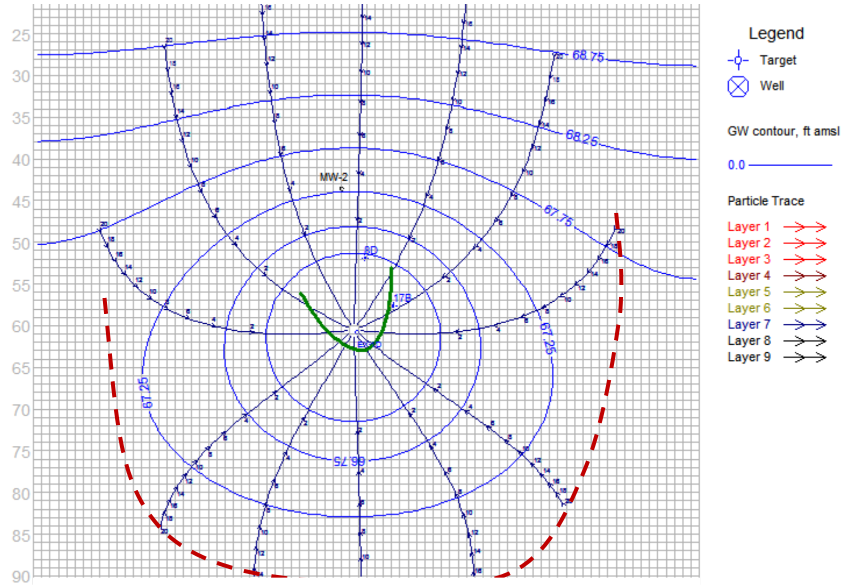
Model Layer 6, Well EX-1C:



Note: complete downgradient capture zone not shown

Notes: Green = Required Capture Zone
Red = Calculated Capture Zone

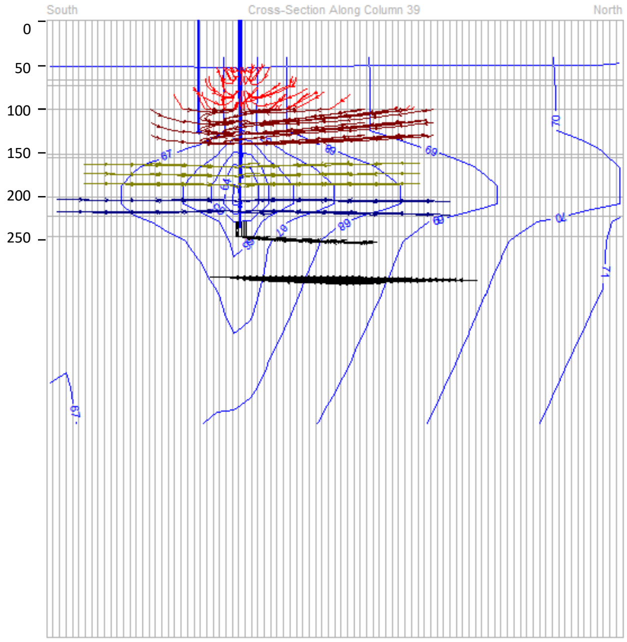
Model Layer 7, Well EX-1D



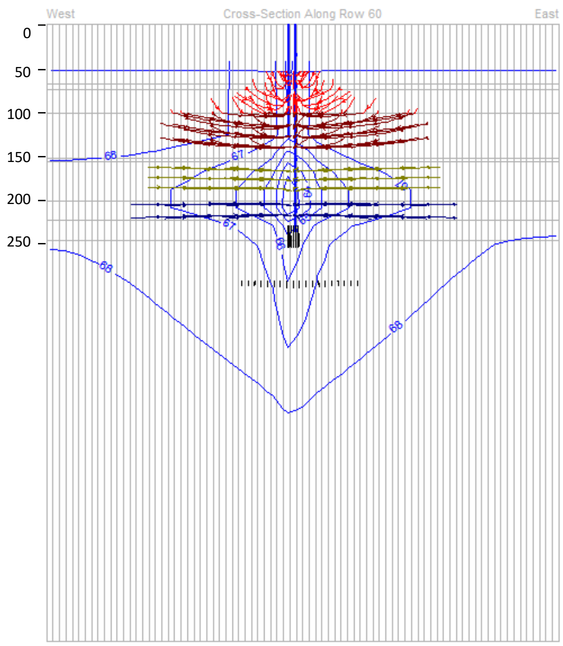
Note: complete downgradient capture zone not shown

Notes: Green = Required Capture Zone
Red = Calculated Capture Zone

Cross Sections, All Model Layers

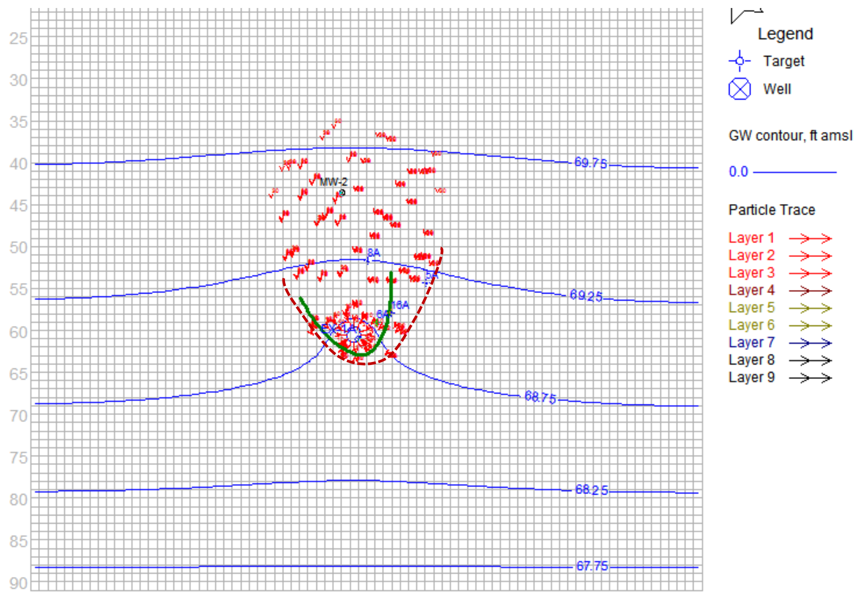


Cross section (up- to down-gradient) through EX-1 locations with reverse particle tracks. Groundwater flow is to left.

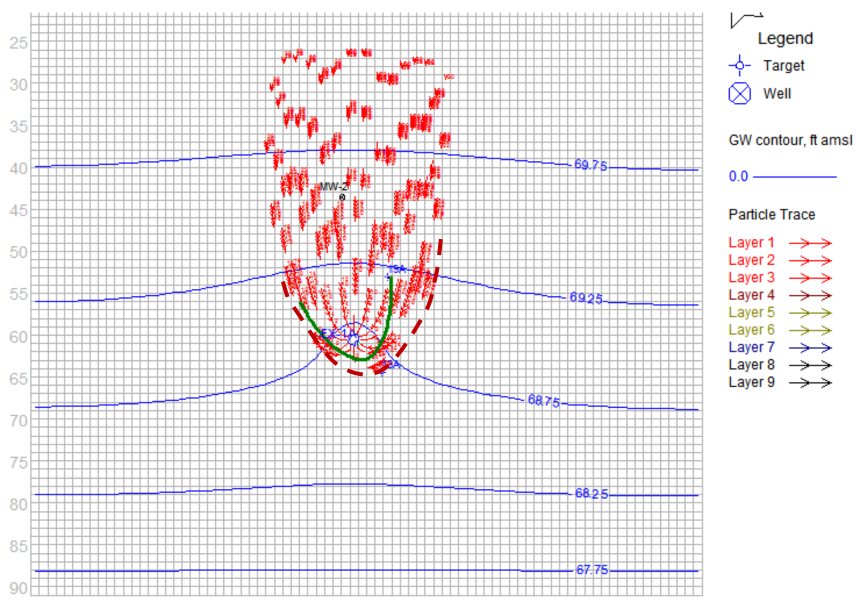


Cross section (west - east) through EX-1 locations with reverse particle tracks. Groundwater flow is out of page.

Model Layer 1, Well EX-1A1 (upper aquifer layer)

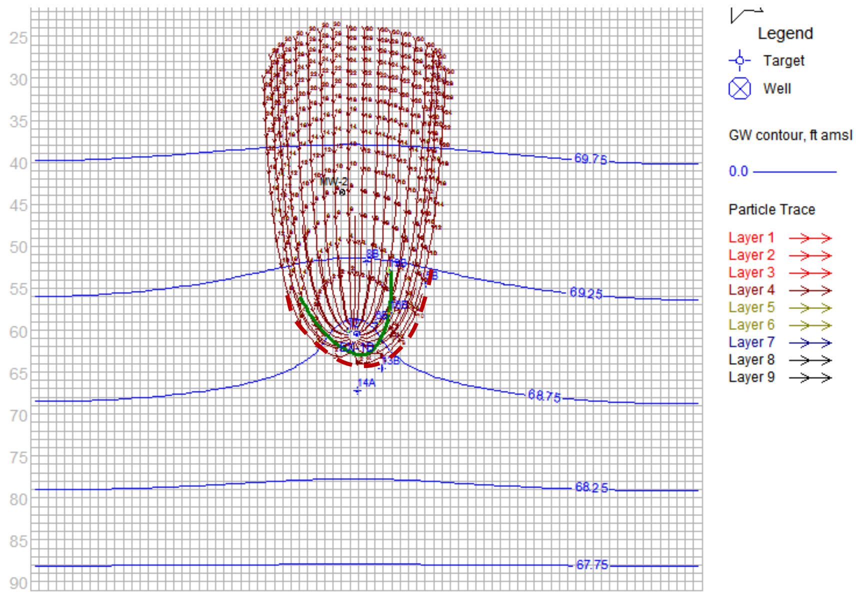


Model Layer 3, Well EX-1A2 (lower aquifer layer)

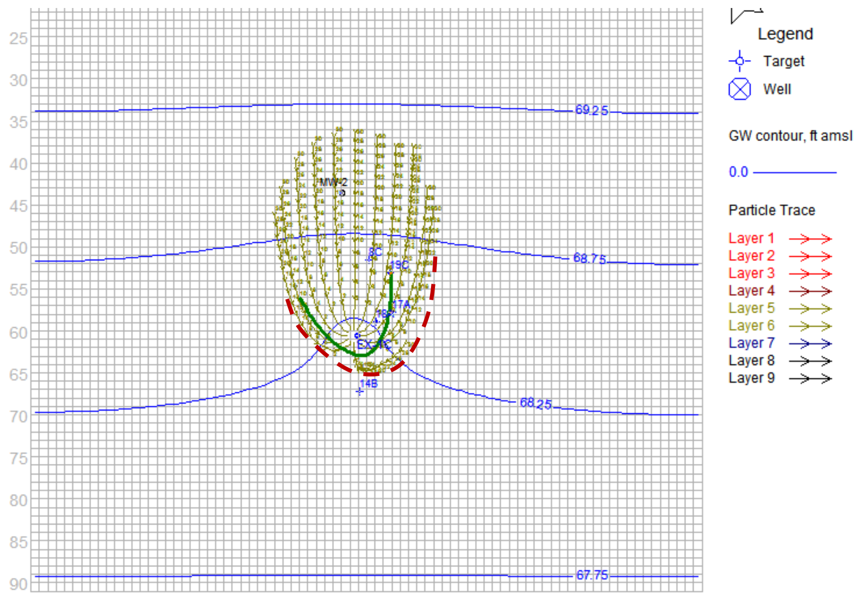


Notes: Green = Required Capture Zone
Red = Calculated Capture Zone

Model Layer 4, Well EX-1B

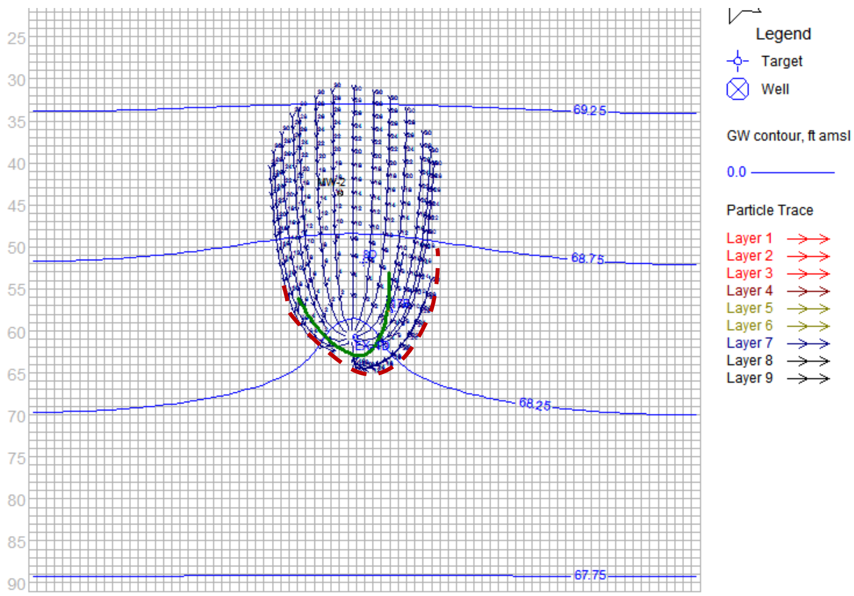


Model Layer 6, Well EX-1C



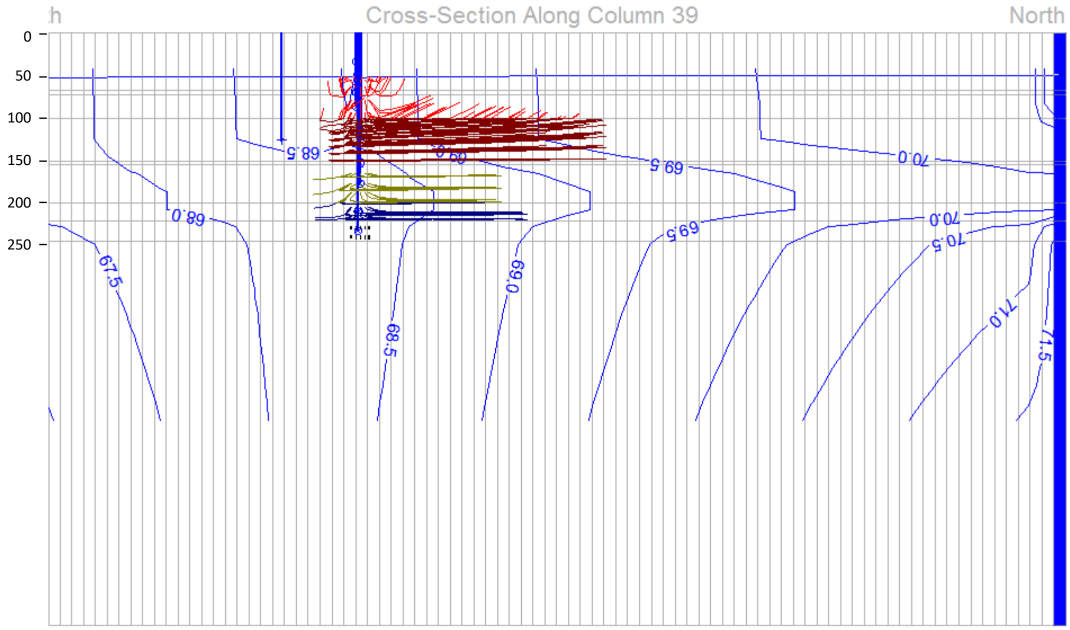
Notes: Green = Required Capture Zone
Red = Calculated Capture Zone

Model Layer 7, Well EX-1D

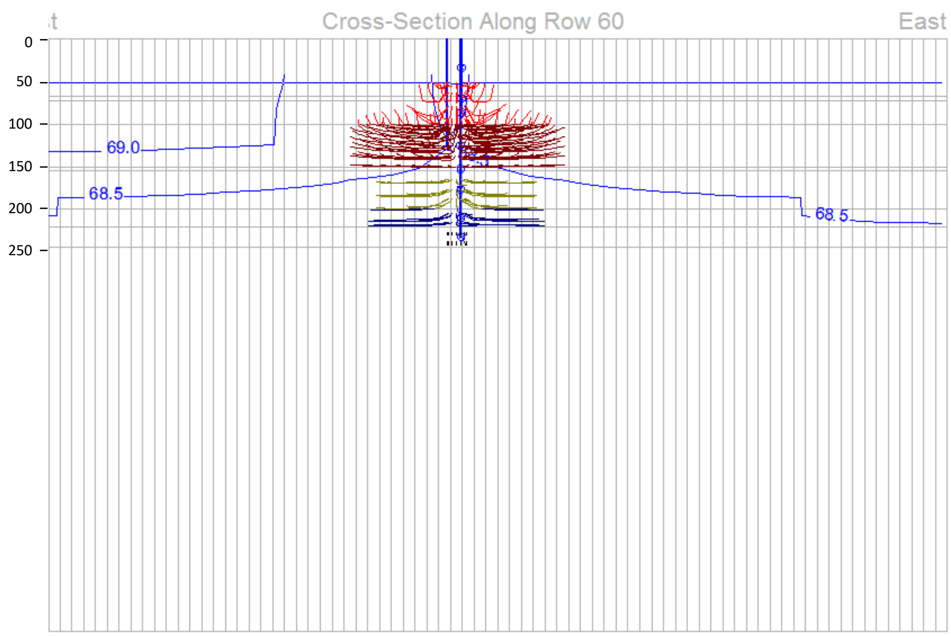


Notes: Green = Required Capture Zone
Red = Calculated Capture Zone

Cross Sections, All Model Layers



Cross section (up- to down-gradient) through EX-1 locations with reverse particle tracks. Groundwater flow is to left.



Cross section (west - east) through EX-1 locations with reverse particle tracks. Groundwater flow is out of page.